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ABSTRACT

Fourth in a series, this loose-leaf guide reviews resources for evaluating, selecting, and using software for teaching mathematics and science skills. Both commercial publishers and public domain sources are listed as sources of educational software. Sources of information on software selection are divided into journals and newsletters, books and special publications, information clearinghouses, and human and organizational resources. A section on methods of describing and evaluating educational software for science and mathematics includes two evaluation forms, developed by the National Council of Teachers and the National Science Teachers Association, which contain descriptive application and evaluation criteria for use with science and mathematics programs. Evaluation criteria related to science and mathematics are discussed, and a section on software applications presents data on the educational use of mathematics and science software programs as well as suggestions for curriculum integration and applications. A brief summary calls for revitalization of science and mathematics instruction through use of the computer. Eighteen references are listed. (JB)

GUIDE TO SOFTWARE SELECTION RESOURCES:

PART FOUR

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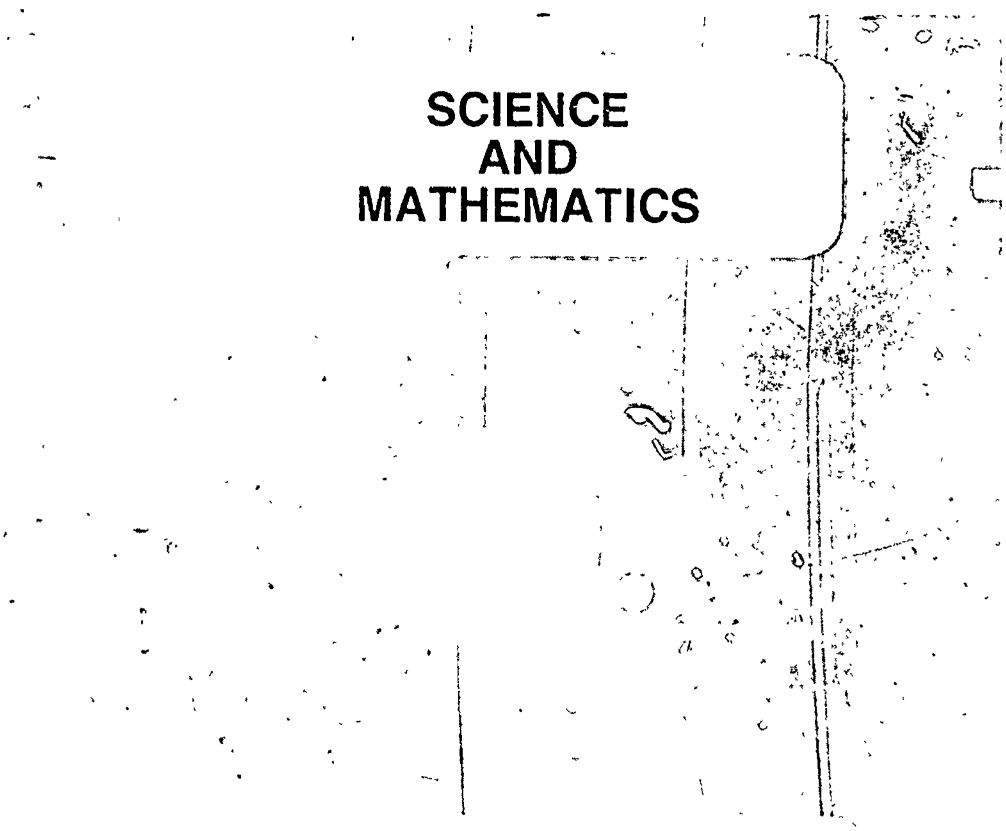

SCIENCE AND MATHEMATICS

THE UNIVERSITY OF THE STATE OF NEW YORK
THE STATE EDUCATION DEPARTMENT CENTER FOR LEARNING TECHNOLOGIES
ALBANY NEW YORK 12230

AND

THE NORTHEAST REGIONAL EXCHANGE

GUIDE TO SOFTWARE SELECTION RESOURCES:

PART FOUR

SCIENCE AND MATHEMATICS

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THE UNIVERSITY OF THE STATE OF NEW YORK
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NORTHEAST REGIONAL EXCHANGE, INC.

The Northeast Regional Exchange, Inc. (NEREX), a private, not-for-profit corporation, is a service and research agency that promotes educational equity and improvement. NEREX coordinates resources and sharing of information among the seven state departments of education in the Northeast based on an established set of state and regional priorities. Through NEREX, states are able to expand their available resource base and work through regional sharing efforts toward program improvement in local school districts and other educational institutions. The Northeast Regional Exchange, Inc. is governed by a Board of Directors that includes the seven Chief State School Officers from the Northeast and eight representatives from a wide variety of education constituency groups in the region.

Acknowledgments

Part IV of this Guide was written by Charles Mojkowski of Technology Applications Associates, Cranston, Rhode Island. Research assistance was provided by Tim Barclay of Technical Education Research Centers (TERC), Cambridge, Massachusetts. George Hanify of the Merrimack Education Center, Chelmsford, Massachusetts and Mr. Barclay provided helpful reviews of early drafts of the text.

Parts I and III of this Guide were written by Charles Mojkowski of Educational Consulting Services, Cranston, RI Part II was prepared by Nancy Baker Jones of the Southwest Educational Development Laboratory and Larry Vaughan of the Northeast Regional Exchange, Inc.

Robert Caldwell, chairman of the National Council of Teachers of English Committee on Instructional Technology, provided resource information used in Part III.

Foreword

As with all instructional material, the selection of appropriate educational computer software is one of the most important responsibilities of teachers and administrators. In these early stages of the development of educational applications of the microcomputer and other interactive learning technologies, it is important to establish a strong foundation for our uses of these powerful new tools. Unfortunately, it has become commonplace to hear criticism of much of the available microcomputer educational software. Unless high quality materials are used appropriately, the power of the technology will be wasted.

Recognizing the critical role of software in computer-based teaching and learning, the Center for Learning Technologies of the New York State Education Department and the Northeast Regional Exchange are pleased to provide this resource series for teachers and administrators. It provides information on resources and tools for locating software and assessing its appropriateness for various instructional applications. The purpose of the series is not to identify "good" software for educators, but to provide a means through which teachers can make decisions about appropriateness and quality within the context of their curriculum and instructional needs.

This **Guide to Software Selection Resources** has been designed as a resource series to aid the decision making process in schools. The series includes both generic and content area resources. Part IV is the second of the content-specific materials, it focuses on science and mathematics. Continued collaboration between the Center for Learning Technologies and the Northeast Regional Exchange will yield additions to this **Guide** to focus on other curriculum priorities.

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Overview

The purpose of this **Guide to Software Selection Resources** is to provide teachers and administrators with a reference tool for identifying, evaluating and selecting software for use in computer-based teaching and learning. The **Guide** is organized as a series of modules that deal with different aspects of the process.

Part I provides an overview of software selection and general educational technology resources in New York State. This section serves as a preamble to the remaining sections of the **Guide**, which deal with software selection resources in specific content areas. Special emphasis is placed on the organizational and material resources that are available throughout New York State to assist educators in implementing meaningful applications of computer technology, particularly software.

Part II is a general purpose introduction to evaluating software. Prepared by the Northeast Regional Exchange, Inc. and the Regional Exchange of the Southwest Educational Development Laboratory, **Evaluation of Educational Software: A Guide to Guides** serves as an introduction to criteria, procedures and sources of software evaluation information.

Part III deals with software selection information and procedures relating to reading and communication skills. Part IV is devoted to resources for selecting software for science and mathematics instruction. Subsequent updates of the **Guide** will deal with additional subject areas, as well as new general purpose resources.

A number of assumptions explain the approach we take in the **Guide**:

- Software evaluation and selection is only one component of a comprehensive computer program development and implementation process. This process requires the identification and use of a wide range of information and assistance resources available throughout New York State.
- The selection and evaluation of software is primarily an educational task and only secondly a technical one. However powerful and sophisticated the microcomputer may be, the pedagogical quality of the software is what determines its value in supporting teaching and learning. Thus, while evaluation of software may be a relatively new activity, the evaluation of traditional instructional materials has been taking place for many years. Such evaluation forms the foundation for selecting software.
- Evaluating instructional materials requires an understanding of the teaching and learning context in which the materials will be used. What is "good" instructional material in one setting may be unacceptable in another. For this reason, we have avoided evaluating or recommending specific software. This is not to say that software evaluation is solely a matter of individual judgment, there are accepted standards and procedures that can be applied. This **Guide** deals with such standards, and explains how they can be used by teachers and administrators.

- The amount of software is growing rapidly, as are sources of information about it. This manual presents a "snapshot" of information available presently. Updates will be prepared as time and resources permit, helping teachers and administrators to keep up with new developments.

The loose-leaf format of the **Guide** allows you to add your own resources, as well as incorporate the updates provided by the Center for Learning Technologies. The Center would appreciate receiving copies of materials you identify so that they may be included in future editions. Please send them to:

Center for Learning Technologies
New York State Education Department
Cultural Education Center
Empire State Plaza
Albany, NY 12230

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INTRODUCTION

It is difficult to deal with educational software resources for science and mathematics without attending to the pervasive and growing concern about the curriculum itself. Several national studies and reports :ited the inadequacy of K-12 science and mat. ıatics instruction for preparing students to live and work in an increasingly technological society. Major initiatives at national, state and local levels have been or are being formed to address these inadequacies and recover, if not preserve, our country's worldwide leadership in technology.

Recommendations for the new science and mathematics curriculum include substantial amounts of content on technology. This technology also is a major source of support for the needed innovation and improvement. Rapid advances in hardware and software are serving as a principal motivation to rethink the content and processes of science and mathematics instruction and also are making it possible to implement some of those changes in the classroom.

Software selection for use in teaching science and mathematics must be linked closely to the curriculum itself. This **Guide** reflects that concern. It is written to help teachers, and others concerned with using computers and related interactive technologies, to more effectively teach science and mathematics. Despite the relatively large amount of softwar. available in these areas, we are still at an early development stage in terms of effectively using computers and software to teach.

This part of the **Software Selection Guide** is devoted to resources for selecting software for science and mathematics instruction. As with Part III, dealing with software for reading and communication skills, this part builds upon the general resources and procedures discussed in Part II, **Evaluation of Educational Software: A Guide to Guides.** It is addressed to the following questions ,aised by an increasing number of teachers.

- Where can I find software for teaching science and mathematics?
- Where can I find descriptive and evaluative information on software used in teaching science and mathematics?
- What subject-matter standards can I use to assess the quality of the software available?
- Where can I find information to help me use appropriate software in my teaching?

SOURCES OF EDUCATIONAL SOFTWARE

A relatively large amount of software is available for use on microcomputers and is appropriate for math and science educational applications, K-12. The Technical Education Research Centers (TERC), in a study conducted for the National Institute of Education, found that, as of May 1983, there were about 1,000 commercially available software titles in math and about 750 in science, and that approximately 100 new titles were being added each month. To this quantity must be added the large number of public domain and locally developed software that is available to educators. Significantly more than half of the software runs only on the Apple. This is especially the case in the more advanced areas of math and science where the software market is thin.

In spite of the large number of titles, there is far from uniform coverage of math and science topics that are taught at the precollege level. There is almost no elementary science software, and many high school math topics have no supporting software. Software in biology is dominated by games and simulations, many in ecology. Topics such as human physiology and medicine are inadequately addressed, if at all.

Math software is strongly oriented toward elementary grades. For math, most titles are available for sixth grade, with large numbers for grades 3 through 8. Science software, on the other hand, is highly concentrated at the high school level. The largest number of titles is available for the twelfth grade, with decreasing numbers in the lower grades.

A spring 1983 survey of computer use in New York State conducted by the Center for Learning Technologies in the New York State Education Department found that science and mathematics software were among the most frequently used. Of all schools reporting the use of software, nearly seventy percent reported using mathematics material and thirty-five percent reported using science software.

The amount of science and math software is considerably larger than that for all other subject areas. Scores of publishers produce and distribute software in these areas. A selected list of software publishers and distributors, both commercial and public domain, is provided in the following sections.

Commercial Publishers and Distributors

The following publishers of software either specialize in software for science and math or have extensive portions of their materials devoted to the subject areas.

The Cactusplot Co.
1442 N. McAllister
Tempe, AZ 85281

Cambridge Development Lab (CDL)
100 Fifth Ave.
Waltham, MA 02154

COMPress
P.O. Box 102
Wentworth, NH 03282

Computer Curriculum Corporation
Represented by:
Instructional Systems, Inc.
560 Sylvan Avenue
Englewood Cliffs, NJ 07632

Conduit
P.O. Box 388
Iowa City, IA 52244

Creative Publications
3977 E. Bayshore Rd.
P.O. Box 10328
Palo Alto, CA 94303

Cuisenaire Company of America
12 Church Street
P.O. Box D
New Rochelle, NY 10805

Educational Activities
P.O. Box 392
Freeport, NY 11520

Educational Materials and Equipment Co.
P.O. Box 17
Pelham, NY 10803

EduTech, Inc.
634 Commonwealth Ave.
Newton Centre, MA 02159

HRM Software
175 Tompkins Ave.
Pleasantville, NY 10570

The Learning Co.
4370 Alpine Rd.
Portola Valley, CA 94025

Learningways, Inc.
98 Raymond Street
Cambridge, MA 02140

MECC
2520 Broadway Dr.
Saint Paul, MN 55113

Microcomputer Workshops
225 Westchester Ave.
Port Chester, NY 10573

Micropi
Box 5524
Bellingham, WA 98227

Ontario Institute for Studies in Education
252 Bloor Street West
Toronto, Ontario, Canada M5S 1V6

Microphys Programs
2048 Ford Street
Brooklyn, NY 11229

Programs for Learning
P.O. Box 954
New Milford, CT 06776

Quality Educational Designs
P.O. Box 12486
Portland, OR 97212

Spinnaker Software
215 First Street
Cambridge, MA 02140

Sunburst Communications
39 Washington Ave.
Pleasantville, NY 10570

Vernier Software
2920 S.W. 89th Street
Portland, OR 97225

Wadsworth Electronic Publishing Co.
20 Park Plaza
Boston, MA 02116

WICAT Systems
358 South Main Street
Marlborough, CT 06447

John Wiley & Sons
605 Third Avenue
New York, NY 10158

While these publishers will provide information on their products, contacting each may be unnecessarily time-consuming. Traditional school suppliers are beginning to distribute a large selection of software from a wide range of producers. In the Northeast, the following companies distribute science and mathematics software, and have catalogs which make the identification and procurement of applicable material more efficient.

J.L. Hammett
Microcomputer Division
Box 545
Braintree, MA 02184
(800) 225-5467

MARCK
280 Linden Avenue
Branford, CT 06432

In addition to computer software in its most typical form — the magnetic floppy disk — a new software medium, the videodisc, is being introduced to support science and mathematics instruction. A small number of publishers already have produced videodiscs for use in science and math education.

Starship Industries
605 Utterback Store Road
Great Falls, VA 22066

Videodisc Design Production Group
Great Plains National Library
University of Nebraska
Lincoln, NB 68583

Video Vision Associates Ltd.
39 East 21st Street
New York, NY 10010

WICAT Systems
P.O. Box 539
Orem, UT 84057

John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10158

The April, 1984 issue of **Electronic Learning** devotes several pages to a description of videodisc software in all curriculum areas, and reviews hardware and educational applications as weli.

Public Domain

All of the public domain software centers cited in Part II (**Evaluation of Educational Software: A Guide to Guides**, pages 83–86) have substantial offerings for science and mathematics. Contact these organizations for specific listings. Public domain sources that focus on science and mathematics software are:

Project Seraphim.
NSF Development in Science Education
Department of Chemistry
Eastern Michigan University
Ypsilanti, MI 48197
Contact: John W. Moore, Project Director
Seraphim is a source of public domain software in chemistry. A list of available software was published in the **Computers in Education Newsletter**, June, 1983 and is updated quarterly. A catalog also is available.

Microcomputer Software Exchange in the Northwestern Section of the Mathematical Association of America
Department of Mathematics
University of New Haven
West Haven, CT 06516
This exchange has programs for teachers and students beyond first-year algebra.

Young People's LOGO Association Software Exchange
1208 Hillside Drive
Richardson, TX 75081
While most of the software is devoted to LOGO applications, the Exchange does have other disks. A catalog is available.

SOURCES OF SOFTWARE SELECTION INFORMATION

Information resources for learning about science and mathematics software and their applications are organized here into four categories: journals and newsletters; books and special publications; information clearinghouses; and human and organizational resources.

Journals and Newsletters

One journal is devoted exclusively or primarily to the use of computers in science and mathematics.

The Journal of Computers in Math and Science Teaching.
Association for Computers in Math and Science Teaching
Box 4455
Austin, TX 78765
(512) 258-9738

The following journals regularly feature articles dealing with the use of computers and instructional software in science and mathematics. These journals also feature articles discussing needed revitalization of the science and math curriculum and the role that computers can play in that reform (see the Bibliography for citations from these journals).

Arithmetic Teacher
Mathematics Teacher
National Council of Teachers of Mathematics
1906 Association Drive
Reston, VA 22091
(703) 620-9840

Science Teacher
Science and Children
National Science Teachers Association
1742 Connecticut Avenue, NW
Washington, DC 20009
(202) 328-5800

School Science and Mathematics
School Science and Mathematics Association
Bowling Green State University
Bowling Green, OH 43403
(419) 372-0151

The Computing Teacher
Department of Computer and Information Science
University of Oregon
Eugene, OR 97403
(503) 686-4414

Classroom Computer Learning
5615 Cermak Road
Cicero, IL 60650
(415) 592-7810

Electronic Learning
Scholastic Inc.
902 Sylvan Avenue
P.O. Box 2001
Englewood Cliffs, NJ 07632
(212) 505-3000

An excellent overview of science software is provided in the April, 1984 issue of **Personal Software** ("Science Software — Like Having an Einstein in the House"). Check the Bibliography for the complete reference.

A newsletter which is devoted almost exclusively to math and science teaching with computers is **Hands On!**, published by Technical Education Research Centers (TERC), Cambridge, MA. The newsletter contains articles on classroom applications and software reviews.

The **Computers in Mathematics Sciences Education Newsletter** provides information on research as well as projects, practices and software. The newsletter is produced by:

National Consortium on Uses of Computers in Mathematical Sciences Education
032 Purnell Hall
University of Delaware
Newark, DE 19711
(302) 451-2140

Books and Special Publications

The very existence of books dealing exclusively with the use of computers in mathematics instruction is testimony to the relatively advanced stage of computer applications in this area compared to other curriculum areas. The following titles offer ideas for using computers and software in mathematics.

Computers in Teaching Mathematics by Peter Kelman et al., Addison-Wesley Publishing Co., 1983.
The work of a team of experienced educators and computer experts, this book contains a wealth of information on a variety of applications. The appendices contain lists of books and software.

Using Computers in Mathematics by Elgarten, Posamentier, and Moresh. Addison-Wesley, 1983.
This is a book of math problems and computer programs organized by topics that fit within the normal high school curriculum: algebra, geometry, trigonometry, number theory, probability and statistics, and calculus.

Turtle Geometry: The Computer as a Medium for Exploring Mathematics, by Abelson and diSessa, MIT Press, 1981.
This book is based on summer classes held at MIT for high school students. It is a rich source of excellent material, but it may not fit into the normal curriculum. An alternative geometry course could be designed using this book as a basis.

Selecting and Using Microcomputers in Science Instruction, by Jean Graef, Cambridge Development Laboratory, 1983.
This book has sections dealing with: 1) ways to use the computer to enhance science education, 2) microcomputer features of special interest to science teachers, and 3) resources for further study.

Information Clearinghouses

The computer-based information databases that give exclusive or primary attention to software and computer applications are described in the resource guide for reading and communication skills. Please see page 7 in Part III for that information.

The ERIC Clearinghouse on Science, Mathematics and Environmental Education is the largest source of information on these content areas. The Clearinghouse is located at:

Ohio State University
1200 Chambers Road, Third Floor
Columbus, OH 43212
Contacts:
Science: Dr. Stanley Helgeson
Mathematics: Dr. Marilyn Suydam

The Clearinghouse provides bibliographies, lists of organizational resources, and information analysis reports on science, mathematics and environmental education.

Human and Organizational Resources

Because there is relatively more activity in using technology in science and math than in other curriculum areas, the number of individuals and organizations with expertise is quite extensive. This list is representative and not exhaustive.

Educational Technology Center
Harvard Graduate School of Education
337 Gutman Library
Cambridge, MA 02138
Contact: Dr. Judah Schwartz
This newly established national center is funded by the National Institute of Education to promote and conduct research on the uses of technology in education, particularly in science and mathematics.

Society for Applied Learning Technology
50 Culpepper Street
Warrenton, VA 22186
Contact: Dr. Raymond Fox
SALT conducts conferences and prepares publications on a wide range of interactive learning technologies. Many of its materials are directly applicable to K-12 schooling, with a heavy emphasis on science and mathematics.

Technical Education Research Centers
1696 Massachusetts Avenue
Cambridge, MA 02138
Contact: Dr. Robert Tinker or Tim Barclay
TERC provides training, publications and consultation on applications of technology to education, with a special focus on science and mathematics, K-12.

Other individuals who work in the application of technology to science and mathematics are:

Jean Greaf
General Manager
Cambridge Development Laboratory
Cambridge, MA 02138

George Hanify
Senior Consultant
NDN Technology Lighthouse
Merrimack Education Center
101 Mill Road
Chelmsford, MA 01824

Dr. Donald LaSalle
Talcott Mountain Science Center
Avon, CT 06001

Adeline Naiman
Director of Software
HRM Software
1696 Massachusetts Avenue
Cambridge, MA 02138

In New York State, there are several sources of information on uses of technology in science and mathematics.

The Association of Mathematics Teachers of New York State
Box 322, RD #5
Creamery Road
Hopewell Junction, NY 12533
The Association has published **Guidelines for Computers in Education.**

The Science Teachers Association of New York State
7 Lawnridge Avenue
Albany, NY 12208
(518) 489-8246
The Association holds meetings and produces several publications relating to elementary and secondary school science.

Southern Tier Technical Assistance Center
Broome-Delaware-Tioga BOCES
412 Upper Glenwood Road
Binghamton, NY 13905
Contact: Mark Kneidinger
(607) 729-9301 ext. 322
The Center maintains an automated software evaluation file on science and mathematics materials. The Center also has developed a robotics curriculum for use in secondary schools.

Herkimer County BOCES
Gros Boulevard
Herkimer, NY 13350
Contact: Everett Carr
(315) 363-8000
This BOCES runs several projects dealing with the use of computers and videodiscs in combination with a planetarium. Training and materials are available.

New York City Public Schools
131 Livingston Street
Brooklyn, NY 11201
Contact: Irwin Kaufman
(212) 596-4434
Information is available on a wide range of K-12 applications of technology in math and science education.

At the New York State Education Department, contact the following individuals for information on science and mathematics instruction:

Douglas Reynolds, Chief
Bureau of Science Education
State Education Department
Albany, NY 12234
(518) 474-7746

Fredrick Paul, Chief
Bureau of Mathematics
State Education Department
Albany, NY 12234
(518) 474-3900

METHODS OF DESCRIBING AND EVALUATING EDUCATIONAL SOFTWARE

The checklists in Part II of the Guide are useful for categorizing and evaluating all software. This section deals with information specific to science and mathematics that should be obtained as a supplement to that in the general checklists. Many of the popular content and professional journals cited previously (see page 4) feature evaluations of science and mathematics software. These evaluations provide examples of how subject matter criteria are applied to software. The Bibliography contains citations of articles devoted to science and mathematics software evaluations.

Essential Descriptive and Application Information

The instruments contained in Part II of this **Guide**, and the form used by the Center for Learning Technologies (see Part I) will serve most requirements in deciding whether undertaking an evaluation of a particular software program is worth your time. Most of the questions in those checklists also can be applied to general-purpose software programs, such as those for manipulating formulas, performing computations, and graphing and plotting data.

The Technical Education Research Centers (TERC) divides science and mathematics software into two categories based on educational style and teaching strategy. One style teaches material "explicitly" through tutorials, demonstrations, dialogs, or drill and practice. This style, using the computer as an instructional medium, is by far the most popular, best represented in the available products, and the most researched. This style is probably most effective when there are a lot of facts or procedures to be learned.

The second style of software includes a number of different teaching strategies, all of which have the student learn implicitly through exploration or use of the computer as a problem solving tool. TERC has termed these "implicit" styles, since the material to be taught is implicit in the software but not expounded explicitly. Categories of software in this style include:

Computer as Modeling Device*

1. **Games.** The material to be learned is an intrinsic part of the game and must be mastered to improve the score. Examples: **Green Globs, Rocky's Boots.**
2. **Simulations.** Models or real situations that provide an opportunity for students to learn about systems that cannot be brought into the classroom because of cost, time, danger, or other reasons. Examples: **Three Mile Island, Energy and Geology Search.**
3. **Microworlds.** Cybernetic environments in which students can explore and solve problems. Examples: **Dynaturtle, Factory.**

*This categorization was developed by Henry Olds in "Evaluating the Evaluation Schemes," in Part II of this **Guide.**

Computer as Tool

4. **Microcomputer-based laboratories.** The computer is turned into a powerful instrument students can use to analyze, display, and save data from experiments. Example: Experiments in Science.

5. **Databases.** Large collections of data that students can access. Examples: **DB Master, Notebook.**

6. **Tools.** Software that solves specific computational or display problems such as graphs and equation solvers. Examples: **TK! Solver, Visi-Plot.**

7. **Computer languages.** General purpose software that students use to program solutions to problems. Examples: **LOGO, DYNAMO.**

Evaluation Criteria Related to Science and Mathematics

Both the National Council of Teachers of Mathematics and the National Science Teachers Association have prepared recommended evaluation forms for assessing software quality and applicability. The NCTM instrument, which appears in Part II on pages 60–61, was one of the first available. The NSTA instrument, on the following pages, is new; it is designed to be used primarily in school-level or district-level evaluations of science instructional software packages. It is reproduced with permission of the National Science Teachers Association.

In general, checklists such as those of NCTM, NSTA and those in Part II of this **Guide** will be of limited utility in assessing the subject content of the software, unless they adequately take into account the subject matter of the institutional program. Deciding whether a specific software package is appropriate for the classroom applications you wish to make first requires an understanding of curriculum standards and guidelines. In addition to the general evaluation criteria listed in Part II, you will need to assess the software against the curriculum standards established at the district and state levels.

The New York State Education Department makes available syllabuses for every curriculum area. At present, these syllabuses do not include standards relating specifically to the use of microcomputers and other learning technologies in science and mathematics curricula. These syllabuses are useful, however, in determining whether the subject matter of the software is addressed to appropriate objectives and activities in the related curricula.

Another way to identify curriculum standards that can be used as a guide to software selection is through an analysis of the recommendations of major study groups. **Educating Americans for the 21st Century** is one of these reports. Prepared by the National Science Board Commission of Precollege Education in Mathematics, Science and Technology, the report delineates specific objectives for improved science and mathematics programs (see pages 43–44 of the report, which is referenced in the Bibliography). The objectives are included here as an indication of the changes that science and math instruction will be undergoing in the future.

Mathematics instruction at the elementary level should be designed to produce the following outcomes:

- comprehensive understanding and facility with one-digit number facts, place values, decimals, percentages and exponential notations
- skill in informal mental arithmetic, estimation and approximation
- ability to use calculators and computers selectively
- basic understanding of elementary data analysis, simple statistics and probability, and fractions
- ability to use some algebraic symbolism and techniques
- thorough understanding of arithmetic operations and knowledge of when each should be used.

At the secondary level there is a need to examine the content, emphasis, and approaches of courses in algebra, geometry, precalculus methods, and trigonometry. Some components in the traditional secondary school mathematics curriculum have little importance in the light of new technologies. The current sequence which isolates geometry in a year-long course, rather than integrating aspects of geometry over several years with other mathematics courses, must be seriously challenged. Some concepts of geometry are needed by all students. Other components can be streamlined, leaving room for important new topics.

- Discrete mathematics, elementary statistics and probability should now be considered fundamental for all high school students.

The development of computer science as well as computer technology suggests new approaches to the teaching of all mathematics in which emphasis should be on:

- algorithmic thinking as an essential part of problem-solving

NATIONAL SCIENCE TEACHERS ASSOCIATION

TASK FORCE ON ASSESSING COMPUTER-AUGMENTED SCIENCE INSTRUCTION MATERIALS

microcomputer software evaluation instrument

VERSION 1983

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GUIDELINES FOR USING THE MICROCOMPUTER SOFTWARE EVALUATION INSTRUMENT

This instrument should help you and your colleagues in examining and discussing the merits of a microcomputer software package intended to be used in science instruction. The instrument provides a sensible process and basic criteria for judging science software packages. It also lets you add criteria which educators in your particular school situation need to consider.

We are interested in evaluating the entire software package, which includes:

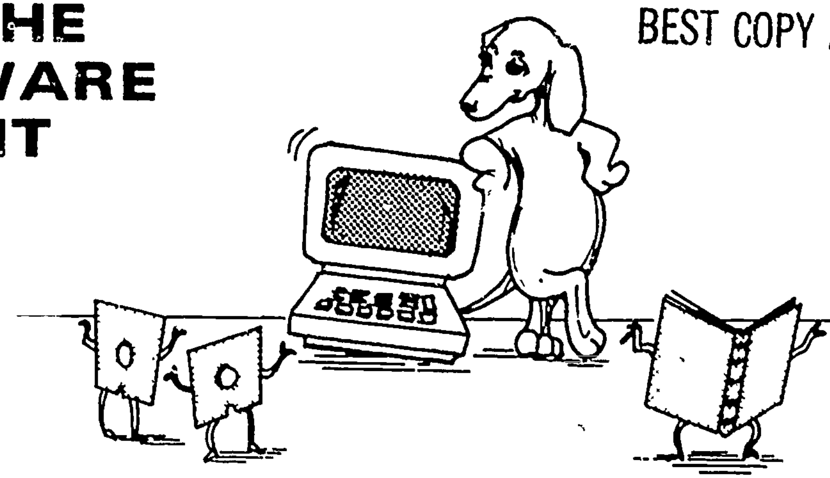
(a) the computer program,

(b) any attendant student instructional materials which are not on the computer, and

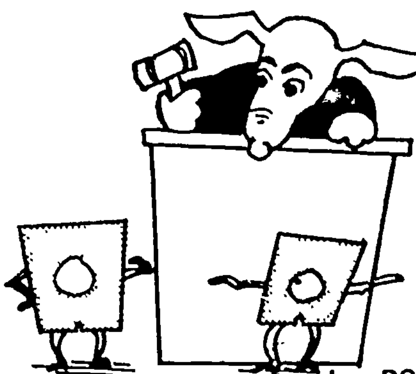
(c) teacher's guide materials and/or program documentation.

The back page of the instument has a space where you can describe the components of the package you are examining, its science content and other characteristics.

The four sections of this instrument call attention to four important aspects of evaluating microcomputer software packages Policy Issues, Science Subject Matter Standards, Instructional Quality, and Technical Quality. Each aspect should be rated separately, and the four section ratings can then be listed to give a profile for the software package. (A box for the profile is on the back page.)



Under each section of the instrument is a set of descriptive criteria pertaining to that aspect of evaluating software packages. Bipolar scales (with + and - values) are used to obtain the rating in each section, so the section ratings of a software package you are evaluating may turn out to be negative, zero, or positive. We (the Task Force members) think that an acceptable package should never have any negative rating in its profile. Probably you and the other educators at your school will want a software package to show strong positive ratings in its profile before you would accept it to be used in science instruction. The exact standard you set for acceptability of software packages should be decided on the basis of your local conditions and your educational good sense.

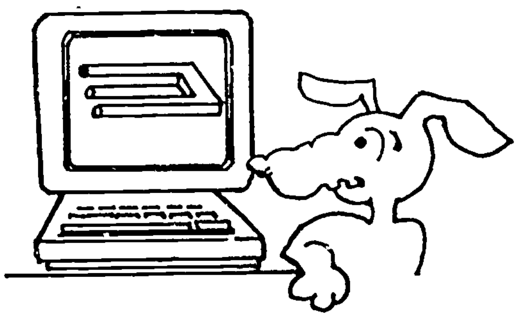


Section P
POLICY ISSUES

This section deals with the most difficult (and, we think, most important) questions that must be answered when any software package is being considered. These questions have to do with the appropriateness, compatibility, cost effectiveness (in both time and money), and instructional effectiveness of the software.

They include such concerns as these: Are the computer's special capabilities utilized to provide a learning experience not easily obtainable through other media? Does the computer program make good use of the student's time on the computer? Is the software package compatible with the goals and theoretical base of the school's instructional program? Does the computer encourage interaction among students while they are using it? What evidence is available that students attain the learning objectives of the software package? If you have other concerns of similar importance in your local situation, they should be added to the criteria of the Policy Issues Section.

Some people have suggested that, if a software package is seriously deficient on the criteria in the Policy Issues section, then it need not be given much further consideration. You should decide about this for your local evaluation pro



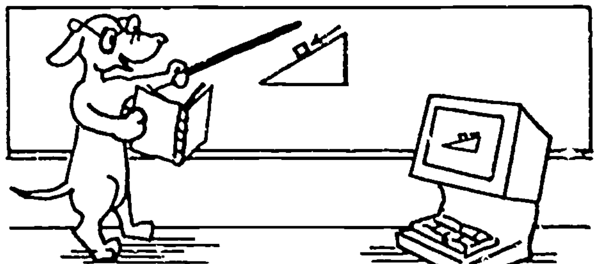
Section S
SCIENCE SUBJECT-MATTER STANDARDS

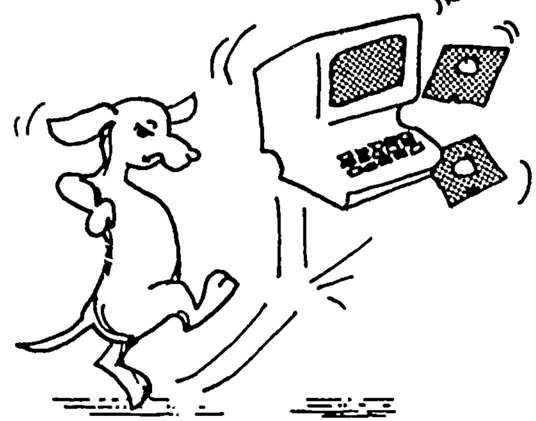
Good science instruction must present good science. To assure that science software packages meet this expectation, this section is concerned with the accuracy of science content, the sound application of science processes, the absence of stereotyping, and other issues related to the honest representation of science in instruction.

There is ample space in the section for adding (if you want to) subject matter criteria that are important in particular science areas.

Section I
INSTRUCTIONAL QUALITY

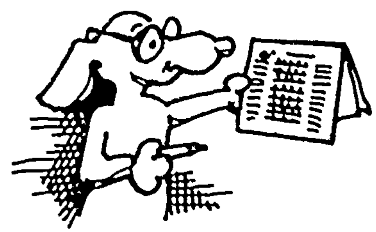
This section is concerned with matters of effective pedagogy, application of good instructional design principles, adaptability of the software to students' individual differences, assessment of students' learning, and the role envisioned for the students using the software package. You should add any omitted criteria that you think are particularly important for good instruction.





Section T
TECHNICAL QUALITY

The focus of this section is the technical quality of both the computer program and the other components of the software package. We are concerned with how well the computer program runs, how carefully its operational features are designed, and how well-designed the accompanying student and teacher materials are. Additional criteria may be needed here if you have particular computer hardware requirements or other expectations for a reliable software package.

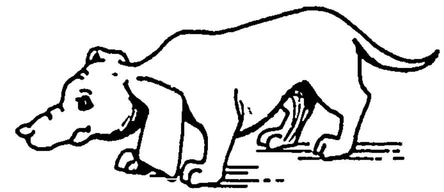


MAKING YOUR RATINGS

Each section of this instrument contains a set of bipolar scales. (Any criteria you add should be constructed with similar scales.) You should carefully consider the descriptions at both ends of each scale and then assign a value on the 3 to + 3 scale according to how well the left or right description applies to the software package you are judging. Mark only one point on each scale. (If you cannot make a decision about a particular scale, mark the zero point for the scale.) To obtain the rating for each section, find the arithmetic sum of the values you assigned to all the scales in the section. You can enter the section ratings in the Software Package Profile box on the back page. The lower portion of the profile box should list the minimum standard you have determined for acceptability in each section. A comparison of the obtained ratings with the minimums can lead to a recommendation concerning the suitability of the software package.

SECTION P

POLICY ISSUES



	LEFT DESCRIPTION IS Definitely True −3	Partly True −2	Slightly True −1	Neither Description Applies 0	RIGHT DESCRIPTION IS Slightly True +1	Partly True +2	Definitely True +3	
The program makes the computer act as little more than a page turner or workbook.								The program exploits the computer's special capabilities (e.g., graphic animation, simulation) to provide a learning experience not easily possible through other media.
The program is wasteful of the limited time available for students to use the computer.								The program makes good use of the student's limited time on the computer.
The purpose and learning objectives of the software package are vague.								The purpose and intended outcomes of the of the software package are clearly defined.
The software package is in conflict with or irrelevant to the goals of the school's instructional program.								The software package is compatible with the the goals and theoretical base of the school's instructional program.
The program expects one student to work on the computer and not to interact with anyone.								Two or more students are encouraged to interact with one another while using the computer program.
There is little or no evidence that students attain the learning objectives of the software package.								The evidence that students attain the software package's learning objectives is convincing.
The software package is incompatible with the learning objectives and instructional materials of a current course.								The software package fits in well with other instructional materials already being used in particular courses or classes.
This software package's cost is exorbitant for what it delivers.								The total cost of this package is reasonable compared to its instructional value.

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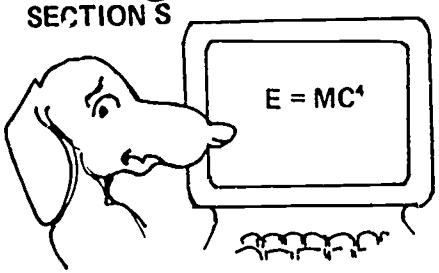
SECTION S



SCIENCE SUBJECT-MATTER STANDARDS

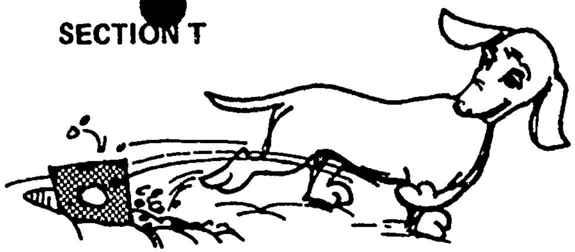
	LEFT DESCRIPTION IS				RIGHT DESCRIPTION IS			
	Definitely True −3	Partly True −2	Slightly True −1	Neither Description Applies 0	Slightly True +1	Partly True +2	Definitely True +3	
The package presents topics which are irrelevant to the educational needs of the intended students.								The topics included in the package are very significant in the education of the intended students.
The science content is very inaccurate.								The science content is free from errors.
Racial, ethnic, or sex-role stereotypes are displayed.								The presentation is free of any objectionable stereotyping.
Biased or distorted information is paraded as factual information.								Well-balanced and representative information is presented.
The package includes science information which is greatly outdated.								The science content presented in the package represents current knowledge.
The presentation of the science content is confusing.								The science content is very clearly presented.
The package gives no attention to the processes of scientific inquiry.								Science inquiry processes are well-integrated into this software package.

SECTION I

INSTRUCTIONAL QUALITY

	LEFT DESCRIPTION IS			Neither Description Applies	RIGHT DESCRIPTION IS			
	Definitely True −3	Partly True −2	Slightly True −1	0	Slightly True +1	Partly True +2	Definitely True +3	
The student is given very few choices that control how he/she works in the computer program's environment.								The program offers the student several options about the content to work on, the level of difficulty, and the rate of presentation.
The student using the program is passive and does little more than punch keys occasionally.								The student is actively involved in interacting with the computer's program.
The instructional strategies used in the computer program do not take pertinent research results into account.								The program's instructional strategies are based on relevant educational or psychological research findings.
The program cannot easily adapt to differences in students' ability, prior knowledge, or learning style.								The program has options which allow it to accommodate students' individual differences.
The software package fails to inform students about its learning objectives or the available activities.								Directions in the software package tell students where they will be going (objectives) and what they will be doing (activities).
The software package's instructional strategies and evaluation procedures ignore pertinent pedagogical principles.								The instruction used in the software package incorporates good sequences, motivating features, and evaluation procedures.
The software package expects that all students will attain the same level of achievement.								Students using the software package can experience success in attaining learning objectives at several levels of sophistication or difficulty.
The software package makes no provision for managing various instructional resources in a classroom.								The software package incorporates a management scheme for deploying available instructional resources.

SECTION T



TECHNICAL QUALITY

	LEFT DESCRIPTION IS: Definitely True −3	Partly True −2	Slightly True −1	Neither Description Applies 0	RIGHT DESCRIPTION IS: Slightly True +1	Partly True +2	Definitely True +3	
Students require an unacceptable amount of guidance by teachers to successfully operate the program.								Students can easily and independently operate the program after a modest period of orientation.
Feedback given by the program to student responses is inappropriate and confusing.								The program's feedback to student responses is appropriate, informative, and timely.
The program's graphics displays are crude and cluttered.								Graphics displays are crisp and clear.
The program's stance is callous and insulting.								The program is "user-sensitive."
The program has uncorrected "bugs" which cause it to behave inconsistently under certain circumstances or to "crash."								All possible combinations of user input and variable ranges are anticipated by the program, making its operation predictable and reliable.
Program documentation is incomplete, confusing, and inconsistent with the observed behavior of the program.								Program documentation is comprehensive, clear, and consistent with observed program behavior.
Student instructional materials *other than* the computer program are poorly organized, unattractive, and inappropriate.								Instructional materials *other than* the computer program are well-designed and appropriate for the students who will use them.
Teacher's materials in the software package are shabby, incomplete, and written in "hacker's" vernacular.								Teacher's guide materials are attractive, comprehensive, and suitable for the teacher-user who has little technical computer knowledge
The software package is physically flimsy and easily sabotaged.								The package's components are designed to survive classroom conditions.

Title of Software Package: ______________________

Publisher or Distributor: ______________________

Evaluators: ______________________

____

SOFTWARE PACKAGE PROFILE

	P	S	I	T
RATINGS				
Minimum Standards				

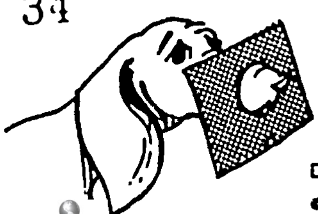
Section P POLICY ISSUES
Section S SCIENCE SUBJECT-MATTER STANDARDS
Section I INSTRUCTIONAL QUALITY
Section T TECHNICAL QUALITY

16

The 1983 Version of this instrument was developed by our task force after more than a year of deliberation and discussion. The first draft was prepared by J.L. Fox and L. E. Klopfer, Learning Research and Development Center, University of Pittsburgh. The 1983 Version is our best current draft, which we expect to revise as computer technology and available software change.

We ask your help in preparing the next version. Information about your experience in using the instrument would be most helpful. Please send your comments and suggestions to:

Task Force on Assessing Computer-Augmented Science Instructional Materials
National Science Teachers Association
1742 Conneticut Avenue, NW
Washington, D.C. 20009



Additional copies of *Microcomputer Software Evaluation Instrument* are available from NSTA Publications.

Design & Illustration: Patricia Winstein Kelley

Comments and Recommendations:

Software Package Description:
(Topics, program type, grade level, print materials for students, teacher guide)

Hardware Requirements:

- student data-gathering and exploration of mathematical ideas in order to facilitate learning mathematics by discovery.

New computer technology not only allows the introduction of pertinent new material into the curriculum and new ways to teach traditional mathematics, but it also casts doubt on the importance of some of the traditional curriculum. Particularly noteworthy in this context at the secondary level are.

- symbolic manipulation systems which even now, but certainly far more in the near future, will allow students to do symbolic algebra at a far more sophisticated level than they can be expected to do with pencil and paper
- computer graphics and the coming interactive videodisc systems which will enable the presentation and manipulation of geometric and numerical objects in ways which should be usable to enhance the presentation of much secondary school mathematical material.

Science and technology instruction at the elementary and secondary levels should be designed to produce the following outcomes:

- ability to formulate questions about nature and seek answers from observation and interpretation of natural phenomena
- development of students' capacities for problem-solving and critical thinking in all areas of learning
- development of particular talents for innovative and creative thinking
- awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests
- the basic academic knowledge necessary for advanced study by students who are likely to pursue science professionally
- scientific and technical knowledge needed to fulfill civic responsibilities, improve the student's own health and life and ability to cope with an increasingly technological world
- means for judging the worth of articles presenting scientific conclusions.

An even more strident voice is heard from Stephen Willoughby who, as President of the National Council of Teachers of Mathematics, states:

> Even more disturbing than our apparent lack of substantial progress in mathematics are the skills in which the students appear to be making progress — lower-order skills such as fact recall and multidigit computation — the very activities that a $10 calculator will always be able to do more efficiently. The back to basics movement, having misidentified what is really basic, is producing youngsters who are slightly better at skills that were of questionable value in the 19th century and will be of little value in the 21st century.

NCTM's **An Agenda for Action: Recommendations for School Mathematics in the 1980s** provides several curriculum standards that can serve as standards for assessing the value of software in helping students learn mathematics. Those of particular import for software assessment are:

1. Problem-solving should be the focus of school mathematics in the 1980s.
2. Basic skills in mathematics should be defined to encompass more than computational facility.
3. Mathematics programs should take full advantage of the power of calculators and computers at all grade levels.

In New York State, the Board of Regents' Proposed Action Plan to Improve Elementary and Secondary Education Results contains several references to a revitalized and more rigorous science and mathematics curriculum. Recommended changes in instructional requirements for grades K-6 include:

> Science — A hands-on approach to learning will be emphasized, with opportunities for experimentation and individual problem-solving. The K-6 science syllabus being developed emphasizes logical thinking and reasoning skills.
>
> Mathematics — The newly implemented K-6 mathematics syllabus focuses on reasoning skills and logical process, and includes application of mathematic reasoning to other disciplines and computer technology. The syllabus gives increased attention to probability and statistics.

For grades 7-12, one additional unit of science and mathematics is proposed, with increased emphasis on science at grade 7-8 levels. In mathematics at grades 7-9, a component on computer use will be required.

The thrust of these and other similar reforms is that science and mathematics will need to improve in quantity and quality, and that technological tools such as the computer are a principal means by which the revitalization can take place. Selecting software before attending to needed curriculum revision may be unproductive, because the improved curriculum constitutes a major standard by which software is to be judged.

Even with the use of revitalized curriculum standards, it is very difficult to judge the utility of available software, since different users look for different properties in software. Many observers feel that software is of quite low quality. For instance, in one report, 4,000 titles were reviewed, and only 3-4% were found acceptable. To some extent, these negative attitudes stem from a lack of fit between available software and an individual teacher's requirements and expectations. One person might reject all drill and practice software as inapplicable, while another might find the perfect remedial lesson among these rejects. As the large number of textbooks for most courses attest, there are great differences of opinion about language, scope, and student autonomy that color teachers' evaluations of software.

In addition to the checklists of technical criteria and the established curriculum standards, there are many basic pedagogical standards through which software utility may be assessed. Odvard Egil Dyrli, in "Science Software in High-Button Shoes" (see Bibliography), asks the question: What should learning science be like? Many of the curriculum standards address this question, but Dyrli believes that there are other, specific questions that teachers need to ask in selecting science software:*

- Does the software help the student see that science is not a verbal activity?
- Is there an opportunity to develop the process skills of students, such as measuring, experimenting, and communicating? Can the software encourage and respond to the students' questions?
- Does the software allow the student to infer or predict the results?
- Does the software make links to the concrete world and the real world? Conversely, can the problems of the world be brought into the software?
- Can the software take in raw data and make it meaningful for the student? Does it provide graphs or charts to help students organize and interpret the data themselves?

The focus of these questions on procedural knowledge rather than on factual knowledge mirrors the direction of all the curriculum reform efforts in science and mathematics. The following section provides descriptions of how the selection criteria — technical standards, curriculum guidelines, and pedagogical principles — are addressed in practice.

*Dyrli's questions were taken from "Science Software—Like Having an Einstein in the House" by Arielle Emmett. Please see the Bibliography for the complete reference.

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SOFTWARE APPLICATIONS: PRINCIPLES AND PRACTICES

Overview of Software Applications

Given the relatively large amount of software that is available for science and mathematics, it is not surprising that applications are more varied than for subjects such as history or literature. In a survey conducted as part of a national study, TERC collected data on the use of science and mathematics software by elementary and secondary teachers. Of those using software, drill and practice was most popular, with seventy-five percent of the respondents using such software. About two-thirds use educational games and computational tools, and about half use simulated labs and other simulations. In keeping with these usage statistics, TERC found an even higher percentage of the commercially available titles are either in tutorial or drill and practice style, including about ninety percent of those in mathematics.

Other usage data from the survey:

> The heavy use of software in advanced science is reflected by the popularity of physics titles (28%) followed by chemistry (25%) and biology (18%).
>
> The elementary grades orientation of math is reflected by the preponderance of basic skills software (76%), especially in arithmetic (34% of all math titles).
>
> The converse of the elementary grades orientation of math software is the paucity of advanced topics like calculus (1.2%), analysis (1.7%), and trigonometry (1.2%).
>
> Drill and practice is very common, especially in math where it dominates with 42% of titles (22% for science).
>
> Combining games, which are usually disguised drill, with the drill and practice category accounts for fully 67% of math but only 26% of science titles.
>
> Games and drills are more common in elementary grades than advanced grades. In math, they drop from 78% at the fourth grade to 62% at the eighth grade and 38% at twelfth grade.
>
> Tutorials are popular, especially for science topics (32%), but also for math (22%).
>
> Simulations are used in 28% of science titles — they represent the most frequently used style in eleventh and twelfth grades.

The statistics for New York State are similar to those for the country. Over 60% of the mathematics software in use in New York State schools is drill and practice. In science the figure is about 26%. The percentage of software used for problem solving in science is 22%; for math, 18%.

Software Descriptions

Descriptions of a few software programs will serve as a means of illustrating the range of software available. No endorsement of these programs is implied.

> **SemCalc: The Work Problem Solver** by Sunburst Communications

One of the major stumbling blocks for students in dealing with word problems is the tendency to focus on manipulating the numbers without paying attention to the units of measure. SemCalc requires that the student attend to the units first before doing the computation. SemCalc can be used by the teacher as an aid to teaching important mathematics concepts.

LOGO. Produced by several publishers.
LOGO is a popular programming language being used in schools, particularly at the elementary level. Its capability includes turtle graphics which establishes a micro-world in which students can explore geometric and mathematical concepts such as angle, direction, geometric figures, position, coordinates and patterns. At the same time, the programming helps to teach sequential thinking and problem solving skills. As a full programming language, it can be used at higher levels of math as well. Because LOGO is a tool, its applications depend on the curriculum context in which it is employed.

The Puzzle of the Tacoma Narrows Bridge Collapse by John Wiley & Sons, Inc.
This "software" is a videodisc that uses the bridge disaster as a means of studying wave motion and resonance. The videodisc is designed for use with a programmable videodisc player. The software narrates the disaster using archival film of the bridge oscillations and collapse. Students can manipulate the variables (wind speed and gust frequency) to study the properties of waves and how specific kinds of waves caused the bridge to collapse. Three levels of difficulty may be selected to accommodate different ability levels of students.

The Factory: Strategies in Problem Solving by Sunburst Communications
This program helps students develop inductive thinking skills and problem solving strategies by having them create geometric products on an assembly line that they design. Students are assisted in analyzing a process, determining sequence, and applying creativity.

DemoGraphics by Conduit
This is a population program which includes a database of 1980 census data for about forty countries, categorized by age groups. Using the program, students can investigate the consequences of the current population variables (fertility rates, life expectancies and infant-child mortality) for any country. Students can also investigate the changes that could be brought about through changes in these variables over time. The software provides a powerful tool for use in social studies and biology.

Green Globs by Conduit
This mathematics software program promotes an understanding of the visual representation of equations. To "destroy" green globs scattered on a set of coordinate axes, students must develop equations which will have lines pass through the globs.

Rocky's Boots by The Learning Company
This game software allows students to build logic machines using traditional logic symbols. The machine is then operated in a game where the winner gets the most points for "booting" characters. The game helps develop an understanding of circuitry and logic.

Without making judgments on the quality of these software programs, it is apparent that they represent a diverse array of tools that can help support revitalizing the teaching of science and mathematics. They provide this support by assisting with concept development or by making more efficient the learning of material that is best done through experimentation. These programs are representative of a larger body of software that moves away from the more common drill and practice to a focus on the development of higher order concepts and skills.

General Purpose Tool Software

There are a number of general purpose tool programs which offer great potential for math and science teaching. The most common categories of these are described here.

Graphing programs. These programs allow students to look at functions, move them around, change the scale, zero in on particular parts of the graph such as a point of intersection or a root, to find the slope, and to extrapolate to much greater values. Most of this provides opportunities for exploration and learning that previously have not been available because of the excessive labor to do these things with pencil and paper.

Data collection and analysis. Collection of data using probes connected directly to the computer is now possible, with display in tabular or real-time graphical format. Students can monitor and plot temperature changes, chemical reactions, and similar phenomena and analyze and display the data for science reports and presentations.

Statistical packages. This software makes it possible to analyze real data. Students can organize and code data and compute statistics.

Equation manipulation. A number of software packages are coming on the market which work with abstract variables rather than concrete numbers, making it possible to manipulate general equations rather than just numbers.

Filing programs and database programs. This software provides the capability to collect, store, sort, and retrieve data which could be collected in the lab or from the environment, and could become a database of information added to by students over time.

Electronic Spreadsheets. This software, of which **VisiCalc** is the most commonly known, allows students to store data and the relations between them in order to study the consequences of modifying either the data or the relations.

The following software programs are representative of the general purpose software which can be used in science and mathematics.

Experiments in Science by HRM Software (similar packages are available from the Cambridge Development Laboratory).
This software package is a series of programs that enable students to use the computer to conduct experiments in biology, physics, chemistry, and earth and planetary science. The package also contains hardware that allows the computer to directly monitor experiments, and measure and plot data. Experiments can be conducted in such areas as reaction kinetics, kinematics, reaction times, and evaporation and humidity.

Electronic Blackboard Series: Algebra and Trigonometry by Wadsworth Electronic Publishing
These graphing tools can be used to create and compare a wide range of functions studied in algebra and trigonometry. By using the computer to generate graphs quickly and accurately, students can focus on the mathematics rather than on drawing skills. Scores of graphs can be developed as students experiment with different equations, deriving the generalizations that are the essence of the lesson. In addition, the software provides tutorial material directed to the experiments.

TK! Solver by Software Arts
This software tool is intended for use in solving problems involving mathematical calculations and analysis. Developed for engineers, scientists, and businessmen as a "word processor" for numbers, the software solves equations, converts units of measurement, plots graphs, and makes tables. Application packs have been created for mechanical engineering, building design and construction, financial management, and introductory science. The last of these provides formulas for such subjects as population growth, chemical equations, gas laws, waves, and acids and bases. It is appropriate for high school use.

These powerful tools offer exciting and innovative potential for the teaching of math and science, both in terms of how we teach and learn, and in terms of what we teach. This potential is largely unrealized at the moment, but is a particularly important area to keep in mind as one thinks of uses in the near future. There appears to be a trend toward developing templates or models for applying standard tool programs, such as **TK! Solver**. Such templates will make it easier for teachers to apply spreadsheet, graphics, and database management software tools to problem solving in science and mathematics.

Curriculum Applications

Teachers have difficulty integrating software into their classroom activities. A large fraction of the software is single topic, i.e., it is designed to explicate a narrow group of ideas in a particular discipline or area. Because the set of single topic software does not provide uniform coverage, teachers must be opportunistic at using software when and if it fits the material they want to cover. On the other hand, there are some comprehensive software packages that cover a range of topics over an extended period. However, comprehensive packages can be even more difficult to use in the classroom because any given package may not address the topics the teacher wants to cover at the reading level and concept level that is deemed appropriate for the particular group of students. The very size of these packages makes them difficult to review.

The use of microcomputers in mathematics is advanced compared to its use in science. Mathematics teachers tend to have brought the microcomputers into middle and upper grade schools and tend to have more microcomputers available for their use. However, many faculty in math, as well as in science have only one or a few microcomputers accessible to them, and thus tend to emphasize applications such as demonstrations that require only a single computer per class. Thus, the large number of tutorials and other applications that assume one or a few students per computer cannot readily be utilized by most faculty at this time.

It is not surprising that the most popular way that math and science teachers have for using computers involves no software at all, but rather involves teaching how to program in BASIC. This is probably attributable in part to the fact that many math and science instructors are unusually computer literate and are called upon to teach computer programming courses. It also reflects the fact that many teachers feel that the most educationally sound way of using the microcomputer is to have students solve problems by doing their own programming.

The most significant impact of microcomputer software on education will be through the changes it both requires and makes possible in the appropriate scope and sequence of topics covered in the school curriculum. Experts argue that microcomputers permit less emphasis (and time) on certain topics currently covered in the curriculum, and allow the earlier introduction of new ideas and new topics which heretofore have not been thought possible to introduce. Experts argue that there can be much less emphasis on arithmetic computation and on rote memorization. Plane geometry can be introduced much earlier and its important concepts can be taught in far less time. The idea of proof by theorem, which is often linked with geometry, can be introduced in another context, making geometry itself more accessible. Numerical techniques that are used to solve differential equations can be introduced as soon as students have completed the equivalent of a first-year course in algebra, long before they know what a derivative is.

In the space created by these changes, a number of additional topics can be covered. The conceptual basis of much of high school science can be introduced starting in the fourth grade with microcomputer-based laboratories. High school students can solve college-level problems using numerical techniques. Students can be introduced through the computer to psychology, physiology, perception, nutrition, health, oceanography, geophysics, and many other topics.

These proposed changes in science and mathematics curricula can take place without the computer, but it is unlikely that the impact of such curriculum revitalization will be fully realized without support from new learning technologies. It is less clear how the existing curriculum is to be transformed over time to realize the scenario depicted by the futurists, but pockets of innovation are springing up throughout the country, providing some insights. The following program descriptions focus on some of these pockets.

One source of information about exemplary educational programs employing computer technology is the National Diffusion Network. The NDN provides resources to exemplary projects so that they may help other school districts adopt these new practices. The NDN has several technology programs in mathematics.

Computer Assisted Instruction — Merrimack Education Center
Merrimack Education Center
Technology Lighthouse
101 Mill Road
Chelmsford, MA 01824
(617) 256-3985
This program uses CAI software developed by the Computer Curriculum Corporation to supplement basic skills instruction in reading, mathematics, and language arts at grades 6-9.

Utilizing Computer-Assisted Instruction in Teaching Secondary Mathematics
Asbury Park Board of Education
1506 Park Avenue
Asbury Park, NJ 07712
(201) 774-0888
This program uses CAI software to improve student achievement in mathematics. Computer-based instruction is used in teaching algebra, geometry, trigonometry, calculus, and applied mathematics.

Individualized Prescriptive Arithmetic Skills System (IPASS)
Pawtucket School Department
Park Place
Pawtucket, RI 02860
(401) 728-2120
IPASS employs computers and specially designed software as an integral part of both instruction and student performance management in a compensatory education setting at grades 5 and 6.

In addition to these nationally validated computer instruction programs, the following projects can serve as sources of materials and ideas.

Microcomputer Curriculum Project
Price Laboratory School
University of Northern Iowa
Cedar Falls, IA 50613
(319) 273-2548
This non-profit project provides curriculum integrated mathematics software in a wide range of topics for grades 5-12.

TABS-MATH
Ohio State University
1945 N. High Street
Columbus, OH 43210
(614) 422-3449

This project is developing software for elementary grade mathematics in such areas as intuitive geometry, probability, statistics, and estimation. Supplementary curriculum materials also are being developed.

A source of descriptions of additional projects developing and using science and mathematics software is:

Microcomputer Directory: Applications in Educational Settings
Monroe C. Gutman Library
Harvard University Graduate School of Education
Appian Way
Cambridge, MA 02139

National Diffusion Network
1200-19th Street, NW
Washington, DC 20208
(202) 653-7000

EFFECTIVENESS: WHAT THE RESEARCH SAYS

Little is known about the appropriate educational levels for the introduction of some of the ideas discussed above about using the computer. Some anecdotal evidence indicates that well designed software has the ability to make some very abstract ideas quite concrete and accessible at much earlier stages of intellectual development than was ever previously thought possible.

While there are a large number of software titles being produced, there is a need for much more software, particularly programs that focus on problem-solving skills and allow students to undertake their own investigations. There is an urgent need for research on computer-mediated science and math learning. Much of the available software does not have a theoretical basis. It is difficult to know whether the software is even effective, and much more difficult to know what learner characteristics are necessary for its effectiveness. Research is needed on exactly how radical a departure from the traditional math and science curricula is possible with microcomputers.

Unfortunately, only a minority of the software available today is truly revolutionary, in the sense that it permits students to learn substantially more, earlier, with greater ease, and in far different ways than other approaches. It may even be unreasonable to expect a technology to be revolutionary, as this pins hope on a technological "fix" and ignores the continuing problems schools face.

Research tends to indicate that drill and practice and tutorial software does lead to faster and, particularly in remedial applications, better learning. The positive impact, however, is not uniform across student types, as is true of all instruction material, there is a strong student-software interaction which determines effectiveness. Much of the research that supports these conclusions is based upon mainframe computers communicating with teletypes, a mode which is much less attractive than the current generation of microcomputer-based software that uses graphics, animation, and quick interaction. Thus, we expect that explicit instructional materials prepared today with the best software would perform even better in terms of reduced time on task and increased achievement.

Software of this sort can address process-oriented goals, such as problem-solving and scientific thinking, as well as giving students an increased understanding of math and science topics. It is difficult to definitively establish the effectiveness of this kind of software because it is both hard to compare with other approaches, and hard to measure process goals. However, there is some evidence and considerable expert opinion that attest to the value of well designed software of this kind. As indicated previously, however, the quality of the software is only one factor. If the curriculum is poorly designed, good quality software will have limited effectiveness in bringing about the kind of learning that the national curriculum reports are recommending.

SUMMARY

The impetus to revitalize science and mathematics teaching in elementary and secondary schools is increasing. Not only is there public interest and support, educators agree that changes need to be made. The content of those changes, however, is the subject of considerable discussion and some disagreement. The consensus is that new learning technologies, particularly microcomputers, are an undisputed part of such a revitalization. In "Science Education: The Search for a New Vision," Paul DeHart Hurd tells us that science and technology are usually addressed as two distinct fields, while in industry it is their "marriage" which has resulted in the technological society that we have today. The society of tomorrow will be more technologically integrated than today, in ways that we cannot even predict, but ways that today's students will design.

To accomplish their work, students will need knowledge that the computer can provide through drill and practice, tutorial and simulation software. More important, however, the computer will be the tool through which the future is developed and lived. Science and mathematics instruction can be revitalized by the use of the computer, but only if the revitalization begins with a reconceptualization of what science and mathematics students must master in order to pursue further learning and careers in an increasingly technological world.

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