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ABSTRACT

This study examined the extent to which opportunities created by computer technology addresses the needs in school science and mathematics instruction. Information was gathered by obtaining descriptions of most available software; reviewing published software evaluations, grant-supported software development projects, and a broad selection of software; and by consulting experts in the field and school personnel. Among the findings reported are these: although software development is expensive and risky, software production is high; while a large amount of software is available, more high quality and classroom usable software is needed; both normative and descriptive software evaluations are greatly needed; many channels for software dissemination are inadequate to keep teachers fully informed about available software; schools allocate inadequate resources for software acquisition; microcomputer software can increase the range of science and mathematics topics successfully covered; and appropriate software can improve student performance in current courses. Broad improvements in teacher knowledge about the technology and the topics it facilitates, software dissemination, and classroom implementation are recommended to meet identified needs. These recommendations include developing software that teaches problem-solving skills, empowers students, and addresses process objectives. (JN)

SCIENCE AND MATHEMATICS SOFTWARE OPPORTUNITIES AND NEEDS

Executive Summary

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TECHNICAL EDUCATION RESEARCH CENTERS, INC

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I. Introduction

The current state of mathematics and science instruction in U.S. schools is inadequate to the needs of a technological society. At ne same time there are major developments under way in the form of increasingly powerful microcomputers and sophisticated educational software. To what extent can the opportunities created by computer technology address the needs that are being uncovered in school mathematics and science instruction?

This question is the subject of the following report, a summary of research performed for the U.S. Department of Education between September 1982 and May 1983.* In addressing this topic, within the province of mathematics and science instruction, we have obtained descriptions of most available software, reviewed many published software evaluations, acquired a broad selection of software, reviewed most grant-supported software development projects, consulted with experts in this area, and interviewed a broad range of teachers, supervisors, school administrators, school support personnel, and software developers. The results from that research are reported here in summary form. The full report is available from Technical Education Research Centers.

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II. Background.

Approach

Our approach was formative and primarily qualitative; we were not asked by the funding agency to plan a statistically significant design. Our contacts were with experts and/or users of microcomputers in schools. We strove for breadth in terms of geography, computer experience, educational level, and educational role.

Methodology

In preparing this study, we -

- requested catalogs from 619 software vendors.
- prepared a database of over 1,600 software descriptions
- reviewed over 500 software evaluations
- reviewed the literature starting with searches of ERIC, the Microcomputer Index, and RICE databases
- requested over 60 descriptions of software development projects
- asked for assistance from 23 professional groups
- acquired over 100 software titles
- interviewed by telephone 70 developers and school-related personnel
- surveyed in writing 160 developers and school-re'ated personnel
- met twice with our national advisory board
- held two meetings with regional educators.

These project-related activities were supplemented by extensive informal contacts through our research, workshops, conferences, and microcomputer resource center.

Restriction to Mathematics and Science

In the following we refer to mathematics and science exclusively. All other uses of computers, such as computer science, language instruction, and instructional assistance in other disciplines are excluded. All interviews were with teachers, school staff, and vendors concerned with math and science instruction. Thus, our conclusions and recommendations refer exclusively to the math/science part of the educational microcomputer field.

III. Survey of Needs

We wanted to know what the profession felt the major needs were in mathematics and science education.

Needs: From the experts

A number of current studies stress the need for a major effort to improve mathematics and science instructional quality and support:

- We are raising a new generation of Americans that is scientifically and technologically illiterate... Improving science and math achievement among our young people requires a joining together of efforts by educators, parents, the private sector, and all levels of government....
  (National Academy of Sciences, Science and Mathematics in the Schools, 1982)

- Deficiencies in numbers and qualifications of mathematics and science teachers are exacerbated by classroom conditions, including inadequate instructional time, equipment, and facilities....
  (National Science Board, Commission on Precollege Education in Mathematics, Science and Technology, Today's Problems, Tomorrow's Crises, October, 1982)

- Adequate support for materials, equipment and teacher time must be available for schools to maintain quality science instruction.
  (National Science Teachers Association, Position Statement, 1981)

- Improved preservice and in-service teacher education was given top priority....Problem solving was consistently ranked high in priority ....There is consistent and strong support for increasing the emphasis on applications of mathematics throughout the curriculum....
  (National Council of Teachers of Mathematics, Priorities in School Mathematics, 1981)

Needs: From the field

We asked over 200 school people what they felt the major educational needs were in math and science.

- More than half wanted better instructional material: individualized units, material that was more motivating, new curriculum, ways of improving problem-solving skills, and applications-oriented content.

- One quarter of the responses mentioned the need for more instructional support in the form of funds, material, equipment, and space.

- One-fifth cited the need for better qualified and certified teachers and more teacher training.

- Some science teachers are concerned about a decreased emphasis on laboratory experiences.

IV. The State of the Art

We attempted to characterize the current state of affairs concerning the production, dissemination, and use of educational software in math and science.

Development

Although software development is expensive and risky, software production is high.

- More than 160 commercial software developers produce mathematics and science products.

- The rate of commercial software production in mathematics and science is approximately 100 new titles per month with an historical doubling time of less than two years; that is, in 1988 there were only 50 new titles per month.

- Software is expensive to produce and support. Development costs range from $5,000 to $100,000 and more depending on the style and the length of the program.

- The cost of producing a variant of a piece of software for a new machine is considerably less than the cost of the original software.

- Commercial developers are extremely concerned about software piracy. This inhibits software production and dissemination, limits innovation, and drives up prices.

- Many developers are small, address a specialized market, and are academically based. These vendors have low overhead and can efficiently serve a limited market.

- Most software is developed by individuals on a royalty basis, usually without an advance.

- There is great commercial interest in developing products for the home educational market.

- Many imaginative products originated with a grant from the National Science Foundation or other public or private foundations.

- Many teachers use non-commercial software developed by students, faculty, school districts, obtained by swapping, or taken from the literature.

- Authoring languages are not commonly used to develop instructional material.

Availability

While a large amount of software is available, more high-quality classroom-usable software is needed.

- A large number of software titles are now available commercially - 1,000 in math and 650 in science. These represent one-fourth and one-sixth respectively of all educational software.

- Most software is for the Apple, especially in thin-market science fields.

- There is not a uniform coverage of math and science topics. There is almost no elementary science software; many high school topics have no supporting software.

- There is a great overlap of similar approaches and topics covered by various vendors' products.

- Most software is designed for a single topic within a subject area. However, in elementary mathematics and general chemistry there are a few comprehensive software packages which attempt to cover the entire K-6 curriculum.

- The available software, with a very few exceptions, matches the general pattern of current school instructional topics.

- Over 90% of math titles use an explicit instructional style - primarily drill and practice or tutorial.

- Many users feel that most software is unsuitable for their purposes due to pedagogical style or technical inadequacies.

- Very little of the software addresses process-oriented teaching goals.

- As the field matures, more high-quality, imaginative software is appearing at lower cost.

- Very little software is addressed to subgroups of students (e.g., Spanish speaking or special need students).

Evaluation and Review

Reliable software evaluations, both normative and descriptive, are greatly needed.

- Many school personnel expressed a strong need for more software to be evaluated or to be made available for personal evaluation.

- Somewhat less than half of math and science titles are evaluated. This is comparable to the rate for all software. Few reviews are in math and science journals.

- Many groups and journals publish software evaluations, often for the same software. Most evaluations appear in computer magazines and journals rather than in math or science journals.

- Most users expressed great interest in an on-line software directory with contributed evaluations.

Information Dissemination

The many channels for software dissemination are inadequate to keep teachers fully informed about available software.

- Teachers find out about software through many routes. Most important are magazines and journals Word-of-mouth is also quite important.

- Most microcomputer users are aware of only a small part of the available software.

- Catalog distributors are increasingly important because they provide one-stop shopping and some level of evaluation or endorsement.

- Vendors provide an important teacher training role, through confrences, sales presentations, and software distributed on approval.

Acquisition

Schools allocate inadequate resources for software acquisition.

- Individual teachers usually initiate software requests, subject to approval.

- Fewer than 30% of schools have software budgets per se.

- The low-cost software distribution procedure developed by Minnesota Educational Computing Consortium (MECC) has been very successful.

Software Use

Computers are used in many ways but predominantly for teaching programming.

- The most common use of computers by math and science faculty is to teach BASIC. This reflects the widespread use of these teachers to teach programming courses, as well as the use of student programming as an instructional strategy.

- Drill and practice and simulations are also widely used, with drill and practice rated as more important.

- Integration of software into the classroom is difficult. For this reason, the vast majority of teachers prefer small, stand-alone software units, instead of comprehensive packages.

- The most popular software, by far, came from

MECC. Other vendors were mentioned too seldom to be significant.

- Many educators felt they were too inexperienced to recommend any specific educational software.

- The Logo language, contrary to the opinions of many experts, is not widely perceived by teachers as part of mathematics instruction.

- Many observers are concerned that both the quality and amount of microcomputer access is not equitable and that this technology will reinforce inequities present in society.

- Precollege vocational and technical programs seem to have lower utilization of microcomputers.

V. The Software Potential

While software will not redress inadequate staffing or budgets, many observers feel that the right software can be an important part of the response to the educational needs of math and science.

For Increased Learning

Microcomputer software can increase the range of math and science topics successfully covered.

- Inductive, experience-based learning can be enhanced through simulations, games, computer-based labs, and programming.

- Simulations with good graphics and user control were judged the most valuable and needed software style.

- Student use of software tools, like graphing and statistical tools, computer-based labs and scientific databases, could dramatically increase student learning.

- By gaining facility in programming, students can learn mathematics and science concepts, especially using a graphics-oriented, extensible language like Logo.

- Computer availability can change the appropriate scope and sequence of instruction.

- New software such as symbolic equation solvers and expert system and new technologies such as videodisc and lab interfaces, when appropriately ~~used, premise to increase the math~~ and science concepts accessible to students.

- Microcomputers permit increased mathematics and science learning in informal settings, such as the home, libraries, clinics, and museums.

- Process-oriented goals, such as problem-solving and scientific thinking can be achieved with appropriate software.

For Greater Achievement

Appropriate software can improve student performance in current courses.

- The graphics, animation, interaction, speed, "patience," and non-judgemental character of microcomputers can be used with great effectivenesa.

- Using the computer for testing, drill and practice, and games is popular and effective, especially for remediation.

- Well designed interactive tutorials could become an important source of instruction.

- Although the use of microcomputers to manage instruction (CMI) is uncommon, many of those who use it are enthusiastic about its impact.

For Improved Teaching Productivity and Reduced Costs

Although there is some potential for cost reduction, the current uses of computers add instructional costs which are justified by corresponding improvements in quality.

- There is almost unanimous agreement that current software can assist but not replace teachers.

- Cost reductions can be achieved in some CMI and computerized lab situations by reducing the amount of clerical work needed to monitor student work, diagnose student problems, assign units, and calculate grades.

- Computer-assisted instruction can speed learning and free teachers from some rote tasks to make more effective use of their talents.

- The projected large base of computers and educational software in homes can be used by schools to reinforce instruction.

- Technological developments in hardware and software hold promise for increased learning at decreased cost.

VI. Recommendations

To meet the identified needs, broad improvements in teacher knowledge, software dissemination, and implementation are required.

Teacher Training and Support

Almost all mathematics and science faculty, administrators, and trainers must plan a substantial, sustained effort to acquire familiarity with the technology and the new topics it facilitates.

- To exploit the potential of software for increased instruction, faculty must be aware of the software but, in many cases, must learn new underlying substantive mathematics and science content.

- Local or regional technical and instructional support services related to microcomputers should be implemented to provide low-cost, ongoing faculty assistance.

- Local capacity for appropriate training must be increased, by offering summer institutes, developing teacher training materials, and providing support and training for local personnel responsible for in-service courses.

- School administrators and curriculum planners need to continually update their knowledge of software applications.

- Technology-mediated training should investigated, such as the use of broadcast and cable TV, videodisc, and microcomputer software.

- Conferences and vendor presentations are an important part of teacher training that should be encouraged.

- Preservice training in microcomputer applications in mathematics and science instruction should be strengthened.

Software Development

More software should be developed that teaches problem-solving skills, empowers students, and addresses process objectives.

- Because major projects in this area tend to involve large financial risks, foundation or government support is required to encourage innovation and develop bold new approaches.

- Individuals and small developers serving thin markets should be encouraged and supported through technical assistance, more software reviews, better dissemination, contests, and alternative distribution channels.

- There is a great need for quality software, especially for elementary science, for computer-based labs, and for certain other mathematics and science topic areas, particularly in instructional styles that encourage exploration and problem solving.

- Microcomputer enrichments of existing innovative curricula should be developed.

- Mathematics and science software is needed that is designed for special populations such as Spanish speaking, physically disabled, and learning disabled students.

Classroom Implementation

There is a great need for classroom-ready microcomputer-related materials; much of the available software that could be used in teaching lacks the documentation, curriculum integration, and student material needed in the classroom.

- Far more applications software should be in use. Schools must plan and budget for increased software acquisition, and industry should take increased responsibility to help improve the learning environment.

- Schools should develop ways of using computers found in the home by supporting group purchases, circulating software, and lending hardware.

- Teaching material should be developed that takes advantage of students' programming ability..

- There is a need for material geared to common courses that would give teachers guidance for the appropriate use of available software.

Research

There is an urgent need to inquire more deeply into the possibilities of microcomputer technology, into the cognitive basis of computer-mediated learning, into new curricula, and into the social and institutional changes caused by increased microcomputer use.

- Because the technology is in transition, research on new technologies and their educational implications is imperative.

- Effectivenes research on current software, other than drill and practice, is needed to guide schools.

- Radical departures in mathematics and science scope and sequences enabled by microcomputers must be tried and evaluated.

- The issues of equitable access to microcomputers must be carefully monitored along with other institutional changes caused by microcomputers.

- Basic cognitive research and its relation to math, science, and computers needs to be expanded.

Software and Information Dissemination

The dissemination of software and related curriculum information must be greatly improved.

- There is a great need for centers that combine service, research, and development in the area of microcomputers and learning and which have excellent hardware, software, and intellectual resources.

- There is a great need for more reviews of math and science software, especially comparative reviews, reviews based on classroom experience, and descriptive reviews. These should be published in magazines and journals normally read by classroom teachers and school administrators.

- A publicly supported electronic database and message system is needed to share up-to-date information and evaluations of math and science software between schools and individual users.

- The information needs of small software suppliers for new product ideas, teacher needs, distribution channels, and marketing data should be met.

- Alternative software distribution models should be attempted, such as those exemplified by MECC, CONDUIT, APX, and Project Seraphim.

VII. Conclusions

The pattern that emerges is that while microcomputer software holds great promise, its use in mathematics and science instruction in schools is in its infancy. BASIC programming and drill and practice are the most widespread current uses of the technology. Only modest, scattered instructional improvements can be expected by extrapolating current trends.

However, with a major commitment of public and private resources at all levels, substantial improvements are possible in teacher effectiveness and consequent student learning and achievement. To realize these improvements, there must be major efforts to improve teacher training, to develop better software, and to acquire and use appropriate software. Supporting these efforts, there is a need for research on computer-related learning, development of new curricula, increased software evaluation, better dissemination of software information, and response to the equity issues raised by microcomputer use.

About Technical Education Research Centers

Technical Education Research Centers, Inc. (TERC) is a nonprofit research and development organization founded in 1965 and committed to improving the quality and availability of educational opportunities for all people. TERC has conducted well over 100 projects for a variety of national, state, and local governmental agencies, educational institutions, private businesses, and community-based organizations. Project activities include: research, curriculum development, demonstration of model programs, inservice training, technical assistance, evaluation, and materials development and dissemination.

This project was performed at TERC's Technology Center which specializes in the use of electronics and, in particular, microcomputers in classrooms and laboratories of primary, secondary, and post-secondary schools. In addition to curriculum, hardware, and software development, TERC has trained more than 2,000 educators in the use of microcomputers.

Project materials available:

- Executive Summary Report. Abstract of the Project Final Report. 14 pages. $3.

- Project Final Report. Methodology, findings, conclusions, recommendations, bibliography, and a complete listing of math and science software vendors and titles available. 150 pages. $17.

- Review of Commercial Science and Mathematics Educational Software. An analysis of types of commercial software available, present trends, and recommendations for the future. 20 pages. $5.

- The Electric Software Finder. A description of TERC's on-line database of math and science software and instructions for its use. 55 pages. $12.