Computers and Mathematics: A Revolution in Progress

By Clifford Pope, Jr. and Ruth Atkinson Pope

Right now, a revolution is in progress that is as important and as far-reaching as the Industrial Revolution. Those who succeed in the Information Age will be able to use technology to extend mental powers as Industrial Age technology extends people's physical powers. The development of skills associated with the mathematics curriculum is more important today than ever in order to effectively use new technologies and interpret the vast amounts of material being spewed from computers. This article will discuss some ways in which computer technology may help Adventist educators develop pupils' abilities to think, learn, and act.

Drill and Practice—or Problem Solving?

An examination of textbooks and observation of current practices shows that the emphasis in most math classes is on computational skills. The majority of computer programs now used for math can be classified as "drill and practice." Studies indicate that using drill-and-practice software generally produces small but statistically significant gains in student computational skills, possibly as a result of pupils spending more time on task when using the computer.[1,2,3]

Clifford Pope, Jr. is professor of mathematics and applied science at Atlantic Union College, South Lancaster, Massachusetts. He has taught college math and science classes for 17 years. Ruth Pope is special lecturer in education and basic skills at Atlantic Union College. She developed and teaches a course entitled Computers in the Classroom, as well as other classes such as Methods of Teaching Math in Elementary and Middle School.

Picture removed

The development of skills associated with the mathematics curriculum is more important today than ever in order to effectively use new technologies and interpret the vast amounts of material being spewed from computers.

Standardized test results also show that children usually score higher on computational portions of mathematics examinations than they do on those sections dealing with concept development and problem solving.[4,5,6]

Nevertheless, the development of cognitive thinking skills and the ability to understand and solve problems continues to be listed as a major objective of mathematics instruction.[7,8] Problem solving is regarded "as the most significant preparation for the real world because it teaches students to think."[9] Bob Underhill, author of a mathematics methods textbook, states, "Today, we want to use the rules and thought processes of mathematics, along with the facts, to develop a reasoning pattern that will translate to our everyday lives, making us better thinkers."[10]

The math curriculum must develop elementary computational skills, since these are required for estimating and evaluating reasonableness of answers. Drill and practice is important because it can lead to mastery of fundamental knowledge necessary for learning additional concepts.

However, a student cannot apply a principle until he or she understands the concept(s) involved.[11] James H. Wiebe, writing in *School Science and Mathematics*, says that "children should be discovering many principles and concepts themselves—research has shown that children remember longer what they discover, and that they are better able to transfer the discovery to new learning situations than what is merely told to them and memorized."[12]

The computer's capabilities (vast memory; collection, storage, organization, and reorganization of data; information retrieval; graphics; branching; speed of calculations; text manipulation; speech synthesis; ease of management) make it possible to determine quickly what each pupil knows—and doesn't know—so that the steps in guided discovery of concepts "are at the student's level," "contain as many or as few steps and hints as the learner needs," and "are appropriately paced."[13]

Using Logo to Develop Concepts

One of the well-known aspects of computing, the turtle graphics portion of the Logo language, can be used to help students move from the concrete to the semiconcrete, and then to the abstract level of thinking about a concept. For example, initially each child physically moves himself or herself about the classroom to form a rectangle. The semiconcrete stage consists of getting the turtle to perform the same movements on the screen, i.e., making a rectangle, while the abstract step is understanding the characteristics of a rectangle and using its properties in constructing more complicated shapes.

The following concepts, some quite complex, can be taught using Logo: open and closed figures; convex and concave; regular polygons; units of measure; angle measurement; similarity and congruence; procedural definitions of terms such as triangle, square, et cetera; relationships between interior and exterior angles of polygons; variables; recursions; plotting of coordinates; invariance; rotations; slides; histogram plotting; point plotting; and function plotting.[14,15]

These concepts are best learned through the discovery method. Students involved in these activities must be guided by a teacher who has an understanding of Logo language and the computer.

Which concepts are semiconcrete and abstract are relative to the experience of the individual. At the secondary level, for example, watching the graphical addition of two functions on a computer screen might provide the concrete experience a student needs to understand the concept and be able to use it to solve problems.

"Research has shown that children remember longer what they discover, and that they are better able to transfer the discovery to new learning situations than what is merely told to them and memorized."

Computers for Problem Solving

Strengthening problem-solving skills takes a lot of class time; therefore, teachers must incorporate the teaching of concepts and principles of mathematics into interdisciplinary problem-solving activities. "Recent research findings have shown that certain strategies taught to students can significantly improve their problem-solving achievement."[16]

Some teachers are already changing their instruction to concentrate on problem-solving techniques, and so give learners an extended period of time to work on problems. Students are encouraged to investigate alternative approaches and evaluate different

Picture removed

solutions. Computer simulations are being used as a catalyst to stimulate discussion about real-world problems such as pesticide use, food shortages, and nuclear power stations.[17] Students in these situations have the opportunity to use computers to explore problem-solving strategies.

Cooperative Learning With Computers

Software with a format that provides the opportunity for children to work together, e.g., the Search Series,[18] allows students to exchange ideas and learn from one another's unsuccessful as well as successful attempts to solve problems. Contrary to fears expressed by parents and teachers, using computers in schoolrooms has not restricted socialization but has actually enhanced student interaction. Students also learn how to make the group process work.[19]

In *Computers in Teaching Mathematics* Peter Kelman and others say that the computer "may radically alter what it means for students to solve problems,"[20] for pupils "can probe problems, store and retrieve data, test out solutions, simulate problem situations, and calculate results . . . the way real-world problem solvers do."[21]

Move From Concrete to Abstract

"Students of all ages need a solid background with manipulatives before they deal with abstraction."[22]

Standardized test results also show that children usually score higher on computational portions of mathematics examinations than they do on those sections dealing with concept development and problem solving.

Picture removed

> Children in the elementary grades are, for the most part, in the stage of concrete operations, which means they . . . need to be able to use or visualize physical objects when dealing with mathematical abstractions. . . . Thus, whenever it is appropriate while developing math understanding with software, computer programs should ask the child to think of specific concrete experiences that relate to the concept being developed, should ask the child to actually do the manipulations pictured on the screen, and/or should use graphic representations of concrete models on the screen to help clarify symbolic manipulations of abstract discussions.[23]

Because "spatial ability is of importance to the complete learning of many concepts and skills"[24] and correlates "highly with success in abstract mathematics,"[25] using physical objects along with pictorial representations on the screen will improve students' abilities to visualize and mentally manipulate objects.[26] Students who can already do abstract thinking probably benefit most from symbolic instruction and may find the use of manipulatives distracting.[27]

Types of Programs, Software Available

Today, software programs are available that (1) develop concepts about numbers, geometric shapes, classification by attributes, money, probability, metric measurement, et cetera; (2) provide opportunities to explore logical thought sequences, e.g., the Factory,[28] Rocky's Boots,[29] (3) enhance eye-hand coordination and spatial relationships, e.g., Logo, educational gaming, (4) give practice in rounding off numbers and estimating, (5) provide opportunities for decision-making through simulations, e.g. Pesticides,[30] and (6) develop deductive and inductive reasoning skills by such activities as interpreting graphs. However, "not all concepts lend themselves to demonstration on a screen. . . . It is the responsibility of educators to learn how to discriminate, how to recog-

(To page 42)

National Council of Teachers of Mathematics. Reston, Virginia: National Council of Teachers of Mathematics, 1973.
Chasnoff, R. E. *Structuring Cooperative Learning*. Minneapolis, Minnesota: Cooperation Network, 1979.
Clark, H. Clifford. "Individualized Instruction: It Can't Be Done With a Screwdriver," *The Arithmetic Teacher*, 23:1 (January, 1976), 50-53.
Duker, Sam. *Individualized Instruction in Mathematics*. Metuchen, New Jersey: Scarecrow Press, 1972.
Editors. "Projects on Individualizing Instruction," *The Arithmetic Teacher*, 18:3 (March, 1971), 161-163.
Feng, C. C. *Second Course in Algebra and Trigonometry With Computer Programming*. Boulder, Colorado: University of Colorado, 1969.
Henderson, George L. "Individualized Instruction: Sweet in Theory, Sour in Practice," *The Arithmetic Teacher*, 19:1 (January, 1972), 17-22.
Hess, A. L. *Mathematics Projects Handbook*. Reston, Virginia: National Council of Teachers of Mathematics, 1977.
Johnson, David W., and R. T. Johnson. *Learning Together and Alone: Cooperation, Competition, and Individualization*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1975.
Kidd, Kenneth Paul, Shirley S. Myers, and David M. Cilley. *The Laboratory Approach to Mathematics*. Chicago, Illinois: Science Research Associates, 1970.
MacPherson, Eric D. "How Much Individualization?" *The Mathematics Teacher*, 65:5 (May, 1972), 395, 475-478.
McLean, H. W., and D. L. Killian. *How to Construct Individualized Learning Pacs*. Dubuque, Iowa: Kendall/Hunt Publishing Co., 1973.
O'Daffer, P. G., and S. S. Clemons. *Geometry: An Investigative Approach*. Reading, Massachusetts: Addison-Wesley, 1976.
Ransom, W. R. *Thirty Projects for Mathematical Clubs and Exhibitions*. Portland, Maine: J. Weston Walch, Inc., 1961.
Romberg, Thomas A. *Individually Guided Mathematics*. Reading, Massachusetts: Addison-Wesley Publishing Co., 1976.
Swart, William L. "A Diary of Remedial Instruction in Division—Grade 7," *The Arithmetic Teacher*, 22:8 (December, 1975), 614-622.
Sweet, Raymond. "Organizing a Mathematics Laboratory," *The Mathematics Teacher*, 60:2 (February, 1967), 117-120.
Travers, K. J., L. Pikaart, M. N. Suydam, and G. E. Runion. *Mathematics Teaching*. New York, New York: Harper & Row, Publishers, 1977.
Trembley, Phil, and Hope Luke. "A Model for a Remedial Math Program," *The Arithmetic Teacher*, 24:2 (February, 1977), 140-144.
Wisconsin Consortium for Individualized Learning. *Guidelines for Teacher Use in Individualizing Instruction Through Use of Unipacs*. Green Bay, Wisconsin: Wisconsin Department of Public Instruction, 1973.

Computers and Mathematics

(Continued from page 13)

nize 'appropriate' uses of computers."[31]

Choosing Appropriate Software

Here are some guidelines for teachers choosing software for mathematics instruction to consider:

1. Carefully preview software for school purchases. Choose excellent quality materials that meet the needs of your students. "Mathematical software should stress mathematical relationships, principles, and meanings" for "researchers have concluded that students will retain more, achieve higher scores on tests, and be able to transfer more to new situations if they understand what they are doing."[32] Let publishers know what kinds of programs you want.

2. Choose programs that provide an interdisciplinary, problem-solving approach and utilize the computer's unique capabilities.

The majority of computer programs now used for math can be classified as "drill and practice."

3. Consider programs that allow groups of students to work cooperatively without the necessity of continual access to a computer.

4. Choose software that allows students to use the computer the way it is used in real life—to solve problems; gather, store, and retrieve data; reorganize data; manipulate text; et cetera.

5. Choose drill and practice programs that emphasize what you consider to be really important, that are correct factually and algorithmically, and that include a management program for keeping a record of students' progress.

A New Look at What to Teach in Math

With the renewed interest in the quality of education and the feasibility of having computers in every classroom, educators have "an unprecedented opportunity to reconsider why they teach what they teach and whether they should be teaching other skills and ideas altogether."[33] Studies by Jean Piaget and others demonstrate that many youngsters have not reached the maturational level necessary to master some of the concepts currently expected of them.[34]

Adventist educators must decide how to restructure the scope and sequence of math instruction to best meet the needs and abilities of individual students, particularly in the context of multigrade classrooms. Now is the time to integrate computers into the curriculum to take advantage of their capabilities to help each student develop his or her fullest potential.

Since "computers used for in-

Sources of Software for Preview

- Local computer stores and dealers, some of which have an educational consultant and will allow previewing of any material they carry.
- Catalog companies that have a 30-day return policy—the format of many otherwise good programs is not suitable for church schools, and catalog listings may not describe the format.
- Local, county, or state agencies dealing with computers in education.
- Local school districts.
- Computer users groups in your area.
- Other teachers in your conference.
- Public service television programs that preview software for teachers.

struction are no better than the materials they contain,"[35] classroom teachers, curriculum specialists, learning theorists, and computer programmers need to work together to develop software that makes the computer "an interactive, flexible, and powerful medium for teaching and learning."[36] Some believe that by utilizing the unique capabilities of computers, educators can individualize instruction "to achieve the goal of mastery learning, where everyone learns all material essentially perfectly."[37]

Studies indicate that drill-and-practice software generally produces small but statistically significant gains in student computational skills, possibly as a result of pupils spending more time on task when using the computer.

Quality courseware for teaching mathematics that reflects Seventh-day Adventist philosophy needs to be selected and/or developed for church schools. A few denominational educational institutions should be delegated the responsibility of evaluating software, including field testing, and then disseminating the results of these evaluations. Funds must be provided for this purpose. Careful coordination among the institutions involved can prevent duplication of costs and effort.

Because computers are so new in schools, in-depth research is needed to study their impact on the mathematics curriculum, the learner and the learning process, as well as on the role of the teacher. When educators consider the use of computers in the classroom, they should "not be thinking about computers" but "should be thinking about education."[38] □

RECOMMENDED READING

Viggo P. Hansen, ed., *Computers in Mathematics Education* (Reston, Va.: 1984 Yearbook of the National Council of Teachers of Mathematics)

Seymour Papert, *Mindstorms: Children, Computers, and Powerful Ideas* (New York: Basic Books, Inc., 1980)

FOOTNOTES

1 Mike Lally and Iain Macleod, "Development of Skills Through Computers: Achieving an Effective, Enjoyable Learning Environment," *Impact of Science on Society*, 32:4 (October-December, 1982), p. 458.

2 Beverly B. McConnell, *Evaluation of Computer Assisted Instruction in Math, Pasco School District, Final Report* (Pasco, Wash.: Pasco School District, September, 1983), pp. 1, 25. (This report is on microfiche, ERIC—Educational Resources Information Center, ED 235959, pp. 3, 27.)

3 George W. Bright, "Understanding the 'CAI Phenomenon,'" *AEDS Proceedings: The Tomorrow in New Technology, Frontiers in Administrative Computing; Adventures in Instructional Computing* (Hereafter abbreviated *AEDS Proceedings.*) (Washington, D.C.: Association for Educational Data Systems, 1982), p. 220. (This report is from ERIC microfiche, ED 223239.)

4 Kathleen J. Steele, Michael T. Battista, and Gerald H. Brockover, "Using Micro-assisted Math Instruction to Develop Computer Literacy," *School Science and Mathematics*, 84 (February, 1984), 123.

5 Marilyn N. Suydam, "What Research Says: Microcomputers and Mathematics Instruction," *School Science and Mathematics*, 84 (May-June, 1984), 342.

6 Lawrence P. Grayson, "An Overview of Computers in U.S. Education," *T.H.E. Journal*, 12 (August, 1984), 83.

7 *An Agenda for Action*, (Reston, Virginia: National Council of Teachers of Mathematics, Inc., 1980), pp. 1-3.

8 Donald T. Piele, "Computer Assisted Problem Solving in Mathematics," *The Computer: Extension of the Human Mind*, Proceedings, Annual Summer Conference, College of Education, University of Oregon, 3 (July 21-23, 1982), 132. (Hereafter abbreviated C:EHM.)

9 Peter Kelman, et al., *Computers in Teaching Mathematics* (Reading, Mass.: Addison-Wesley Publishing Co., 1983), p. 65.

10 Bob Underhill, *Teaching Elementary School Mathematics* (Columbus, Ohio: Charles E. Merrill Publishing Co., 1981), p. 4.

11 James S. Cangelosi, "Increasing Student Engagement During Questioning Strategy Sessions," *The Mathematics Teacher*, 77:6 (September, 1984), 470.

12 James H. Wiebe, "Needed: Good Mathematics Tutorial Software for Microcomputers," *School Science and Mathematics*, 83 (April, 1983), 285.

13 *Ibid.*, p. 287.

14 Harold Abelson and Andrea di Sessa, *Turtle Geometry* (Cambridge, Mass.: The MIT Press, 1981).

15 Kelman, et al., pp. 95-137.

16 Wiebe, p. 287.

17 Henry F. Olds, Jr., "The Microcomputer—An Environment That Teaches: Exploring the Hidden Curriculum," C:EHM, 81. (ERIC 219859, p. 88.)

18 McGraw-Hill.

19 Olds, p. 81; Mari E. Endreweit, "Kids and Computers: A New Kind of Sociability," *Worcester (Mass.) Telegram* (August 19, 1984), 3E.

20 Kelman, et al., p. 65.

21 *Ibid.*, p. 66.

22 Joanne B. Rudnytsky, "Beyond Drill and Practice," C:EHM, 216. (ERIC microfiche, ED 219879, p. 221.)

23 Wiebe, pp. 283, 285.

24 Charles E. Mitchell and Grace M. Burton, "Developing Spatial Ability in Young Children," *School Science and Mathematics*, 84 (May-June, 1984), 395.

25 Wiebe, p. 291.

26 Robert Sylvester, "Kids Are Learning More Than Their A, B, C's," *A + Magazine*, 2 (September, 1984), 36.

27 Judith A. Threadgill-Sowder and Patricia A. Juilfs, "Manipulative Versus Symbolic Approaches to Teaching Logical Connectives in Junior High School: An Aptitude x Treatment Interaction Study," *Journal for Research in Mathematics Education*, 11 (November, 1980), 373.

28 Sunburst Communications.

29 Learning Company.

30 Sunburst Communications.

31 Sally A. Sloan, "Instructional Uses of Computers: The Good, the Bad, and the Ugly," *AEDS Proceedings, op. cit.*, p. 24.

32 Wiebe, p. 283.

33 Kelman, et al., p. 16.

34 Underhill, p. 5.

35 Grayson, p. 81.

36 Kelman, et al., p. 2.

37 Alfred Bork, "The Fourth Revolution—Computers and Learning," C:EHM, 17.

38 Sloan, p. 24.

Motivating Math Students

(Continued from page 7)

ticipate in various hands-on experiences, such as taking bites out of a graham cracker until they think what is left is a gram mass. They then weigh it and the student who comes the closest to a gram wins. We also measure the room all over with a meter stick or try a ball-throwing contest in which students measure in meters the distance the ball has traveled.

Another invaluable aid that I use with students who have not yet learned their multiplication tables is math sticks. This activity involves ten craft sticks and some grosgrain ribbon. The numerals 1-10 are listed across the top and down the side of the first stick. The other sticks list vertically multiples of the number at the top of each stick. When the sticks are completed, they constitute a multiplication fact table. The student can use the sticks to assist him in mastering facts he has not yet learned. An added benefit of the sticks is