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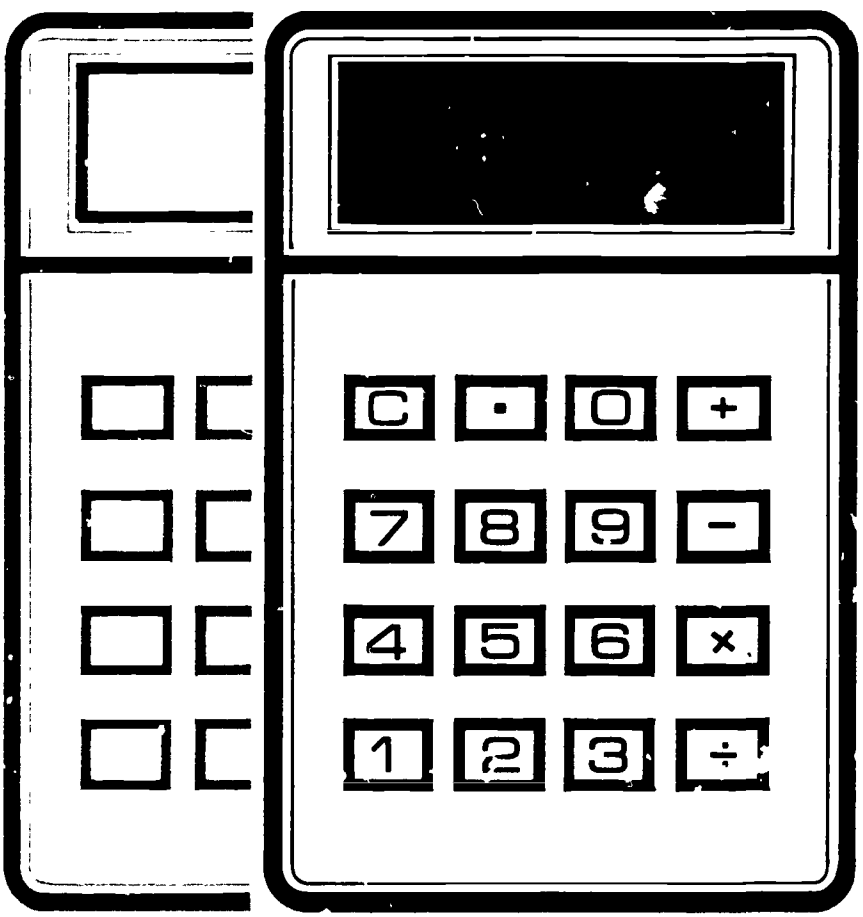
ABSTRACT

These guidelines were developed to provide assistance to Alberta schools in the development of policy for the use of calculators in classrooms, and also to provide some assistance to teachers in planning appropriate experiences for students. A position statement advocating the use of calculators as both instructional and computational aids is presented. Guidelines for their use are then given by level (primary, intermediate, junior high, high school). A research summary is included as Appendix A; Appendix B contains suggestions for calculator selection; Appendix C details the National Council of Teachers of Mathematics recommendation on calculators; and Appendix D provides summaries of some individual research reports. Finally, Appendix E presents the policy statement on the use of calculators on provincial examinations. (MNS)

GUIDELINES FOR THE USE OF CALCULATORS GRADES 1-12



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FOREWORD

The guidelines in this document have been developed to provide assistance to school jurisdictions in the development of policy for the use of calculators in classrooms. The guidelines are intended to be flexible so that school jurisdictions can make modifications to suit their specific needs. In addition, these guidelines provide some assistance to the teacher in planning appropriate experiences for students.

A. POSITION STATEMENT ON CALCULATORS IN THE CLASSROOM

Alberta Education encourages the use of calculators in Alberta classrooms. Their use and potential as instructional and computational aids provides new and meaningful alternatives and opportunities in the learning process. It must be strongly emphasized that the calculator is not a replacement for the learning of basic facts and mental computations.

As teaching devices calculators can contribute significantly to mathematics and mathematics-related subjects. As instructional aids, they can assist in the development and reinforcement of mathematics concepts and processes, and motivate students to experiment with mathematical ideas. While their application in mathematics is obvious, their use can be extended to other subject areas. As computational tools they reduce the time needed to solve problems, thereby allowing an opportunity to emphasize mathematical processes and applications. Through effective use calculators can improve student attitudes and motivation. It is apparent then that the calculator should not be viewed solely as an instrument to achieve rapid and accurate computations.

Other electronic devices that provide immediate feedback to students based on programmed questions and game activities are not to be confused with calculators. These devices can be used to reinforce computational skills through drill.

B. GUIDELINES FOR THE USE OF CALCULATORS

1. The use of the calculator is encouraged throughout Grades 1-12.

When used appropriately, the calculator helps to foster exploration and experimentation, and develop and reinforce concepts. As well, the calculator facilitates problem solving and encourages student interest in mathematics and mathematically-related subjects.

a. Primary Level (Grades 1-3)

The calculator should be used to extend, verify and explore mathematical ideas.

It is recommended that one or two calculators be used occasionally at an interest centre. Seldom should the calculator be the focus for the entire class. Constructive use individually, or in a group mode supported by task cards, is encouraged.

It must be emphasized that calculators provide alternative or supplementary experiences for young children, but the continued use of manipulative material such as centimetre cubes, attribute blocks, numeration blocks etc., for initial teaching is essential.

b. Intermediate Level (Grades 4-6)

Whenever possible the use of calculators is encouraged to support the attainment of the objectives of the curriculum.

Calculators should be used in the two following areas:

i. As an instructional tool in the development of appropriate concepts in the Mathematics Program.

ii. As a computational tool in problem-solving situations.

To facilitate the instructional use of calculators, it is strongly recommended that a classroom set of calculators be available at each elementary school.

c. Junior High Level (Grades 7-9)

The use of calculators as an instructional tool is encouraged in the attainment of appropriate curriculum objectives.

The computational use of calculators is recommended where long and/or extended computations are required. Students should receive instruction regarding the capabilities and proper use of the calculator prior to using it as a computational tool.

Classroom sets of calculators should be available for use in the junior high school.

d. High School Level (Grades 10-12)

The use of the calculator as a computational tool is strongly recommended.

Similar to the junior high need for instruction in calculator literacy, there is also a need for such instruction at the senior high level.

In view of the frequent use of calculators in high school mathematics and science courses, all students should be encouraged to purchase and maintain their own calculators.

2. The ease and speed with which computations can be made on a calculator should not be regarded as a substitute for learning the basic skills. The value and importance of the essential learning objectives are the primary consideration.

3. Students should be encouraged to use calculators in imaginative ways for exploring, discovering and developing mathematical concepts, but care must be taken that the calculator does not become a replacement for other well-proven strategies.

4. There will always be the need for students to possess paper-and-pencil computational skills. The use of calculators does not replace needed understanding and skills in mathematical operations and algorithms. The calculator can assist in solving problems or obtaining correct answers if the right buttons are pressed. If the student does not know which numbers to use and how to use them the calculator will be of no use.

5. Introduction to the calculator does not presuppose that a student has mastery of the basic facts or computational skills. For example, at the elementary level students can successfully explore number patterns with a calculator without knowing the basic facts.

6. Students should be allowed time to explore the capabilities of the calculator prior to directed activities. Knowledge occurs when students are encouraged to become acquainted with a new learning device through exploration and discovery. However, they should be discouraged from using the calculator solely or primarily for checking paper-and-pencil work.

7. The selection and purchase of a calculator should be guided by the grade level and the nature and purpose of instruction.
(The Calculator Selection Guidelines on pages 9-11 address this question more closely.)

8. Calculators should be provided to students who simply cannot master the basic skills, in order to meet their arithmetic needs.

While the vast majority of students will have no difficulties in meeting grade expectations in computational facts and procedures, a small but significant proportion of students may never master these skills. Use of the calculator may facilitate the learning of some mathematics and help to create a positive attitude towards mathematics in general.

9. At the local level, the use of calculators in district or school examinations should be governed by a policy statement that is common to all schools within the jurisdiction.

On provincially mandated high school examinations, the use of calculators is governed by THE POLICY STATEMENT ON THE USE OF CALCULATORS ON ALBERTA EDUCATION EXAMINATIONS. (See Appendix E.)

10. Prior to the introduction of the calculator in elementary and junior high schools, it is recommended that:

    i. an in-service program for teachers be implemented
    ii. parents be informed as to the intent and procedures employed in introducing calculators into the classroom.

APPENDIX A
Research Summary

1. Availability

Data from the Second Mathematics Assessment of the National Assessment of Educational Progress (NAEP) supports the fact that many children have access to calculators outside of the classroom: 75% of 9-year-olds, 80% of 13-year-olds, and 85% of 17-year-olds either own their own calculators or have one available to use (Carpenter, 1981).

2. Instructional Use

Data from studies continue to support the fact that students who use calculators for instruction achieve at least as high or higher scores on mathematical achievement tests than students not using calculators, even though the calculator was not used on the tests. The NAEP results show that with very limited orientation, students do perform routine computation better with the aid of a calculator. With respect to problem-solving techniques, the performance of 9- and 13-year-old students using calculators was poorer than that of students without calculators. Comparisons of problem-solving performances at all age levels with and without the aid of calculators provides convincing evidence that calculators do not solve problems, people do. Strategies, such as trial and error, that take special advantage of the calculator need to be introduced, developed and encouraged. Problem-solving requires far more than computation--it demands understanding, correct choice of operations, and selection of values to operate in a particular order. It is then, and only then, that calculators become helpful tools.

In another study of grade six students, it was reported that students who solved problems with the aid of calculators used a larger number and variety of processes than did the non-calculator group. Both groups had received six weeks of training in problem-solving processes. There was no significant difference, however, in the time taken to solve the problems. It was noted that the non-calculator group spent more time computing and the calculator group more time analyzing the problem (Wheatley, 1980).

3. Attitudes

When beliefs and attitudes are surveyed, it becomes obvious that many persons ignore the evidence from research on achievement and learning. Perceptions of the uses and importance of calculators in the mathematics curriculum depend primarily on the audience surveyed. The Priorities in School Mathematics Project (1979) devoted about 20% of its items to ascertaining how educators at all levels from primary through college, parents, and school board members feel about the use of calculators. Educators were much more supportive of increased use of calculators than were non-educators: 54% of the educators but only 36% of the non-educators would increase emphasis on them during the 1980's. Strongest support came from supervisors and teacher educators (85% and 74%, respectively); teachers at all levels had more reservations (support averaged 50%); and parents and school board members gave weak support to increased emphasis.

With regard to the attitudes of children, there seems to be evidence that calculators positively influence students' immediate reactions concerning their feelings about themselves and the problem they have just completed. Evidence supporting more general and lasting attitudinal changes is not available (Roberts, 1980).

Bibliography

A Position Statement on Calculators in the Classroom, Reston, Virginia: National Council of Teachers of Mathematics, September, 1978.

An Agenda for Action: Recommendations for School Mathematics of the 1980's, Reston, Virginia: National Council of Teachers of Mathematics, 1980.

Carpenter, Thomas P. et al. Calculators in Testing Situations: Results and Implications from National Assessment. The Arithmetic Teacher, Reston, Virginia: National Council of Teachers of Mathematics, January, 1981.

Immerzeel, George et al. Teaching Mathematics With the Hand-Held Calculator, Cedar Falls: Iowa Problem-Solving Project (ESEA Title IV-C), 1978.

Bibliography (cont.)

Priorities in School Mathematics (PRISM). Final Report, ERIC: Ed SE 030 577-578, 1979.

Roberts, Dennis M. The Impact of Electronic Calculators on Educational Performance, Review of Educational Research 50. Washington: The American Educational Research Association, Spring, 1980.

Suydam, Marilyn N. Using Calculators in Pre-College Education: Third Annual State of the Art Review, Columbus, Ohio: Calculator Information Center, August, 1980.

Wheatley, Charlotte L. Calculator Use and Problem-Solving Performance. Journal for Research in Mathematics Education 11. Reston, Virginia: National Council of Teachers of Mathematics, November, 1980.

Appendix B
Suggestions for Calculator Selection

There are numerous models of calculators on today's market, not all of which are suitable for classroom use. Some calculators have features appropriate for elementary school student use but may lack some essential features required for higher level mathematics.

It would not be practical to suggest purchasing one specific brand of calculator because models and prices change frequently. To purchase the most appropriate calculator at the "best" price, it is necessary to consider its functions in relation to the intended levels or educational purposes to be served. A list of desirable features for effective classroom use at the various levels is provided below.

Careful consideration should be given to the purchase of a calculator or a set of calculators for classroom use. A class set of calculators can be a considerable investment, so it is important to compare prices and capabilities. Warranty and availability of service are major considerations which may minimize additional expenditures after the initial purchase.

Selecting a Calculator

The first step in selecting a calculator for use at any level is to assess the needs of the users (students). The following list of features should be considered before a decision is made in regard to purchasing a calculator.

Feature	Comments
Sturdiness or Durability	Check on droppage, malfunctioning incidents, etc.
Type of Logic	Algebraic mode (natural order arithmetic).

Feature	Comments
Type of Logic (cont.)	The numbers and operations are processed in the order in which they are entered. This type of logic has been found most successful with elementary and junior high school students. More sophisticated calculators which automatically insert order of operation rules or parentheses are fairly costly.
Display	Eight-digit display is sufficient. The display should be easily readable (large and clear) and have an acceptable viewing angle especially if more than one person is to view it at the same time. There are two display types available: LED (Light Emitting Diode) and LCD (Liquid Crystal Display). Each one has advantages and disadvantages. The LED is cheaper but has higher battery drain and some are not readable from a wide angle. The LCD is more expensive but has low battery drain and is readable from a wide angle.
Functions	The four operations (+,-,x,÷) are essential at all levels. The percent function is not necessary at the elementary level, but it is necessary at the higher levels. A percent function which allows sum or difference calculation is desirable. The square root function is also necessary for higher level mathematics.

Feature	Comments
Functions (cont.)	Other functions (e.g. trigonometric, logarithmic, etc.) may be deemed necessary at the high school levels. Scientific notation may be desirable at this level. The change of sign key is important if convenient manipulation of integers is needed.
Type of Decimal Notation	Floating decimal--the decimal can be made to appear anywhere on the display. Check the way the calculator rounds off numbers.
Keys	In general, each key should have only one purpose. Preferably, the clear entry key and the clear key should be separate. Function keys should be different in color from numeral keys. Calculators used by elementary students should have keys which offer some resistance or give some response when pressed.
Power Source	Long life replaceable batteries seem to be most cost and time efficient. Automatic shut-off is one feature that can maximize battery life.
Automatic Constant	Allows calculator to count. Usually incorporated in the ⊟ sign. This is only desirable for use at the elementary level.
Memory	Not essential at the elementary level, but it is useful in solving some equations. Very necessary for junior and senior high levels.

Recommendation 3*

Mathematics Programs Must Take Full Advantage of the Power of Calculators and Computers at All Grade Levels.

Beyond an acquaintance with the role of computers and calculators in society, most students must obtain a working knowledge of how to use them, including the ways in which one communicates with each and commands their services in problem-solving.

The availability of computing aids, including computers and calculators, requires a re-examination of the computational skills needed by every citizen. Some of these computational skills will no longer retain their same importance, whereas others will become more important.

It is recognized that a significant portion of instruction in the early grades must be devoted to the direct acquisition of number concepts and skills without the use of calculators. However, when the burden of lengthy computations outweighs the educational contribution of the process, the calculator should become readily available.

With the increasing availability of microcomputers at decreasing costs, it is imperative that schools play an active part in preparing students of the 1980's to live in a world in which more and more functions are being performed by computers.

Recommended Actions

3.1 *All students should have access to calculators and increasingly to computers throughout their school mathematics program.*

- Schools should provide calculators and computers for use in elementary and secondary school classrooms.
- Schools should provide budgets sufficient for calculator and computer maintenance and replacement costs.

3.2 *The use of electronic tools such as calculators and computers should be integrated into the core mathematics curriculum.*

- Calculators should be available for appropriate use in all mathematics classrooms, and instructional objectives should include the ability to determine sensible and appropriate uses.

- Calculators and computers should be used in imaginative ways for exploring, discovering, and developing mathematical concepts and not merely for checking computational values or for drill and practice.

- Teachers should ensure in their classroom management that the use of computers by individual students in isolated activity does not replace the critical classroom interation of students with peers and teacher. The healthy give-and-take of group work and discussion, which promotes values of communication, cooperation, empathy, mutual respect, and much of cognitive development, remains essential.

3.3 *Curriculum materials that integrate and require the use of the calculator and computer in diverse and imaginative ways should be developed and made available.*

- Schools should insist that materials truly take full advantage of the immense and vastly diverse potential of the new media. In particular, developers of software should be cautioned that just to use conventional material and techniques newly translated to the medium of the computer will not suffice.

- Educators should take care to choose software that fits the goals or objectives of the program and not twist the goals and developmental sequence to fit the technology and available software.

3.4 *A computer literacy course, familiarizing the student with the role and impact of the computer, should be a part of the general education of every student.*

- In cooperation with schools and professional teacher organizations, funding agencies should support the development of courses in computer literacy for both junior and senior high school levels.

3.5 *All mathematics teachers should acquire computer literacy either through preservice programs or through in-service programs funded by school districts in order to deal with the impact of computers on their own lives and to keep pace with the inevitable sophistication their students will achieve.*

- Colleges should provide courses for both preservice and in-service education in computer literacy, programming, and instructional uses of calculators and computers.

- Professional organizations should provide information through their various media, conferences, workshops, and seminars to aid in the in-service education of teachers in uses of the calculator and computer.

3.6 *Secondary school computer courses should be designed to provide the necessary background for advanced work in computer science.*

- Curriculum design should provide the required foundation for those students who will be involved in careers that increasingly demand advanced computing skills and applications of computing and for those students who will go on to deeper study in frontier fields of computer development.

3.7 *School administrators and teachers should initiate interaction with the home to achieve maximum benefit to the student from the coordinated home and school use of computers and calculators.*

- Criteria should be developed to assist parents and school personnel in their selection of home/school computing hardware.

- Professional organizations of teachers, mathematicians, and computer scientists should develop guidelines to aid schools, teachers, and parents in the selection of educational software.

- The uses of technological devices such as calculators, computers, video disks, and electronic games in the home and other out-of-school places should be anticipated. Programs should be planned that will encourage the positive and educationally beneficial use of these devices.

- As home computers come into wider use, homework should be assigned that can take advantage of their potential in problem-solving.

3.8 *Educational users of electronic technology should demand a dual responsibility from manufacturers: the development of good software to promote the problem-solving abilities of the student and, eventually, the standardization and compatibility of hardware.*

3.9 *Provisions should be made by educational institutions and agencies to help in the necessary task of educating society's adults in computer literacy and programming.*

3.10 *Teachers of other school subjects in which mathematics is applied should make appropriate use of calculators and computers in their instructional programs.*

3.11 *Teacher education programs for all levels of mathematics should include computer literacy, experience with computer programming, and the study of ways to make the most effective use of computers and calculators in instruction.*

3.12 *Certification standards should include preparation in computer literacy and the instructional uses of calculators and computers.*

* From An Agenda For Action (pages 8-11): A publication of The National Council of Teachers of Mathematics.

Appendix D
Research Reports

(The following research reports were taken from Suydam, Marilyn N., Calculator Information Center, May 1980).

Balka, Don S. A Survey of Parents' Attitudes Toward Calculator Usage in Elementary Schools. South Bend, Indiana: University of Notre Dame, 1979. Teachers in a workshop sent a 12-item questionnaire to parents and teachers of grades k-9; 334 responses were received. Parents were skeptical about the use of calculators in elementary grades. They agreed that calculators could be used for motivation, and along with paper-and-pencil computation, but expressed moderate disagreement with the use of calculators for homework and were very negative about replacing paper-and-pencil computation.

Bitter, Gary. Calculator Teacher Attitudes Improved Through In-Service Education. School Science and Mathematics 80: 323-326; April 1980. No significant difference in attitudes toward calculators was found between primary, middle, and upper grade teachers. A two-hour workshop appeared to improve attitudes significantly.

Chang, Lisa Li-Tze. An Examination into the Effects of Calculator-Assisted Instruction on the Mathematics Achievement and Attitude of Seventh and Eighth Grade Disadvantaged Students. (Cornell University, 1979.) Dissertation Abstracts International 40A: 1323-1324; September 1979. Students (n = 126) in grades 7 and 8 were randomly divided into two groups. For 24 weeks, one group had calculators available during lessons, but not on tests or for taking home; the other group used only paper and pencil. No significant differences between groups were found on computation, concepts, or attitudes; a highly significant difference on problem-solving favored the calculator group.

Cohen, Martin P. and Fliess, Robert F. Minicalculators and Instructional Impact: A Teacher Survey. Pittsburgh: University of Pittsburgh, 1979. ERIC: ED 178 360. Teacher attitudes, practices, and perceptions about school policies on calculator use were surveyed. Over 63% were strongly or mildly in favor of using calculators. The need for instructional materials using calculators was apparent.

Conner, Totsye, J. Effects of Calculator Use in Elementary School Studied at P.K. Yonge Laboratory School. Gainesville: University of Florida, 1979. Two classes each of kindergarten, second-grade, and fourth-grade students used calculators for 10 months. No significant difference in achievement was found in grades 2 and 4; the kindergarten group using calculators scored significantly higher than the non-calculator group.

Creswell, John L. and Vaughn, Larry R. Hand-Held Calculator Curriculum and Mathematical Achievement and Retention. Journal for Research in Mathematics Education 10: 364-367; November 1979. The ninth-grade Fundamentals of Mathematics students using calculators scored significantly higher on immediate tests than students not using them, but no significant retention effects were found.

Engelmeyer, William James. The Effectiveness of Hand-Held Calculators for the Remediation of Basic Multiplication Facts. (University of Maryland, 1978.) Dissertation Abstracts International 39A: 5381; March 1979. Three groups of under-achieving seventh graders (n = 193) participated. One group received 15 minutes extra of practice on multiplication facts with calculator feedback. A second group had 15 minutes extra group instruction on the facts, while a third group had only "normal" mathematics instruction. No significant difference in achievement was found between the two extra practice groups.

Fugate, Barbara Riley. An Assessment of Attitudes, Self-Concept, and Mathematical Achievement Resulting from the Use of Minicalculators. (North Texas State University, 1978). Dissertation Abstracts International 39A: 6531-6532; May 1979. Three fourth-grade and three fifth-grade classes used calculators. Their use did not improve achievement, attitude, or self-esteem.

Krist, Betty J. Using Calculators in Eleventh Grade Mathematics - A Classroom Teacher's Report. Buffalo: State University of New York at Buffalo, 1978. Comments from a teacher using the Math 11 programmable calculator materials developed by Rising et al., are given.

Moser, James M. The Effect of Calculator Supplemented Instruction Upon the Arithmetic Achievement of Second and Third Graders. Technical Report No. 502. Madison: Wisconsin Research and Development Centre for Individualized Schooling, September 1979. ERIC: ED 180 764. Four classes in grades 2 and 3 used calculators with the on-going instructional program, while four classes did not have access to calculators. Significant differences favored the second-grade calculator group only on subtraction and the third-grade group only on place value and division; no other differences were significant.

Noone, Jean Abbott. Effects of the Use of Hand-Held Calculators on Mathematics Achievement and Attitude Toward Mathematics of Seventh Grade Students. (University of Virginia, 1979.) Dissertation Abstracts International 40A: 3849; January 1980. Four seventh-grade classes were randomly assigned to groups using calculators for two months. No significant differences were found between groups on measures of achievement and attitudes.

Ogletree, Earl J. and Etlinger, Leonard. Should Hand-Held Calculators Be Used in the Elementary School: A Survey. Chicago: Chicago State University, February 1980. Teacher reactions to how the calculator might be used in schools were obtained. Generally, it was felt that they should not be used until basic facts are learned, although 96% recognized that children can learn mathematics from using calculators.

Pedersen, Dean Anthony. The Effect of the Calculator on the Elementary Mathematics Student. (University of Northern Colorado, 1978.) Dissertation Abstracts International 39A: 4794; February 1979. Students in grades 2, 3 and 6 (n = 309) were assigned to groups using or not using calculators for eight months. No significant difference in achievement was found.

Reys, Robert E.; Bestgen, Barbara J.; Rybolt, James F.; and Wyatt, J. Wendell. Hand Calculators: What's Happening in Schools Today? Arithmetic Teacher 27: 38-43; February 1980. See also: Wyatt, J. Wendell; Rybolt, James F.; Reys, Robert E.; and Bestgen, Barbara J. The Status of the Hand-Held Calculator in School--Implications for Parents, Teachers and Administrators. Phi Delta Kappan 61: 217-218; November 1979. Results from interviews with 194 elementary and secondary teachers in Missouri are presented. Eighty-four percent said that calculators should be available to children in school. Eighty percent felt that children should master the four operations before using calculators. Almost two-thirds indicated the need for in-service training.

Roberts, Dennis M. The Impact of Electronic Calculators on Educational Performance. Review of Educational Research 50: 71-98; Spring 1980. Thirty-four experimental studies on calculator use are critiqued. Results showed support for the computational benefits of calculator use, but support for conceptual benefits was minimal. Attitude changes were immediate and task-specific Defective research designs were noted.

Roesch, Carl J. Reflecting the New Computation in Eleventh Year Mathematics. Buffalo: State University of New York at Buffalo, 1978. This report presents comments and data from a teacher using the Math 11 programmable calculators materials by Rising et al.

Standifer, Charles Edward. Achievemeni and Attitude of Third-Grade Students Using Two Types of Calculators: (Northeast Louisiana University, 1978.) Dissertation Abstracts International 39A: 5314; March 1978. Nine third-grade classes were randomly assigned to use calculators 8-10 minutes per day for checking and other activities, to use programmed feedback "calculators" 8-10 minutes per day for drill, or to have a traditional paper-pencil approach for 16 weeks. Significant differences favored the calculator group over both others on acquisition and retention computation measures, and the programmed-feedback group over the control group on acquisition. No differences for concepts or attirude were found.

Szetela, Walter. Calculators and the Teaching of Ratios in Grade 7. Journal for Research in Mathematics Education 11: 67-70; January 1980. Students in two seventh-grade classes were randomly assigned to instruction on ratios using or not using calculators for three weeks. No significant differences in achievement or attitude were found between groups on paper-pencil tests.

Toole, Betty Ann Zelig. Evaluation of the Effectiveness of Calculator Assisted Curriculum Instruction in Ninth Grade General Mathematics Classes. (University of California, Berkeley, 1979.) Dissertation Abstracts International 40A: 3852-3853; January 1980. Six ninth-grade general mathematics classes used a calculator-assisted supplementary curriculum during one-fifth of instructional time, while the control group used the regular curriculum. No significant difference was found between groups except for high-scoring students who used the calculator curriculum.

Townsend, Gloria Childress. The Effect of Programmable Calculator Use on Probability Estimation Achievement and Attitude Toward Estimation of Students in Second Year Algebra. (Indiana University, 1979.) Dissertation Abstracts International 40A: 1936; October, 1979. Three Algebra II classes used 10 days to investigate a series of probability exercises. The student-programming group estimated answers and then wrote their own programs to verify their estimates, while a second group used the teacher's program and the control group received results from a hypothetical experiment to verify estimates. Some difference in estimation achievement was noted for the student programming group; attitudes were significantly better than in the control group.

Vannatta, Glen D. and Hutton, Lucreda A. A Case for the Calculator. Arithmetic Teacher 27: 30-31; May 1980. The use of calculators by 36 intermediate-level classrooms in Indianapolis is

described. Materials correlating calculator use with textbooks were provided for teachers. Results after two years of use indicated achievement "well above normal expectations" in computation and problem-solving.

Weaver, J. Fred. Third Grade Students' Performance on Calculator and Calculator-Related Tasks. Technical Report No. 498. Madison: Wisconsin Research and Development Center for Individualized Schooling, July 1979. ERIC: ED 176 992. Refinements of work with calculator algorithms previously conducted by the author are reported. Work with "chaining" and the doing/undoing property in addition and subtraction was tested with 24 third-grade students. Results indicated the need for further instruction with both ideas. Students were able to manipulate the calculator keyboard, but had difficulty with the conceptualizations of the calculations to be executed.

Weaver, J. Fred; Blume, Glendon W.; and Mitchell, Charles E. Calculator Explorations with Seventh Grade Students: Some Calculator-Inspired Instructional Materials, Observations, and Investigations. Technical Report No. 497. Madison: Wisconsin Research and Development Center for Individualized Schooling, July 1979. ERIC: ED 177 019. Observations and instructional materials from calculator explorations with seventh-grade students from 1976 and 1978 are presented. Algebraic-logic calculators with no operational hierarchies were used; at the end of the year, RPN calculators were introduced.

West, Tommie A. The Effectiveness of Two Drill Strategies (Paper and Pencil, Electronic Calculator) in Facilitating the Learning of Basic Multiplication Combinations with Factors of 7, 8 or 9. School Science and Mathematics 80: 97-102; February 1980. Ninety pupils in grades 4-6 were randomly assigned to calculator, paper-pencil, or control groups for two weeks. The calculator group used a preprogrammed "Matheputer". All groups made gains on multiplication fact tests, but the paper-pencil group improved most.

Wheatley, Grayson H. and Shumway, Richard J. Impact of Calculators in Elementary School Mathematics. Final Report, National Science Foundation Grant No. SED77 - 18077, July 1979. ERIC: ED 175-720. See also: Wheatley, Grayson H.; Shumway, Richard J.; Coburn, Terrence G.; Reys, Robert E.; Schoen, Harold L.; Wheatley, Charlotte L.; and White, Arthur L. Calculators in Elementary Schools. Arithmetic Teacher 27: 18-24; September 1979. Two classes from each grade 2-6 in five locations participated, with the class at each level randomly assigned to the calculator group and the other to the non-calculator group. Both groups used the on-going program. No significant differences were found between groups; attitudes of the calculator group were favorable.

Zastrocky, Michael R. Development and Implementation of a Diffusion Model Incorporating the Hand-Held Calculator into a Secondary Curriculum. (University of Northern Colorado, 1979.) Dissertation Abstracts International 40A: 4458; February 1980. The model considered how calculators can be incorporated into a mathematics program. Systems commitment, needs assessment, goals, resources, training, evaluation, and dissemination were discussed.

Zink, Ronald Joseph. The Effects of Using a Programmed Printing Calculator to Improve the Computational Skills of Remedial Mathematics Students in Grades 7-12. (Columbia University Teachers College, 1979.) Dissertation Abstracts International 40A: 4942;; March 1980. Students in grades 7-12 (n = 108) used drill-and-practice programs with or without calculators. No significant differences were found between treatments.

Zweng, Marilyn J. Children's Strategies of Solving Verbal Problems. Iowa City: University of Iowa, August 1979. ERIC: ED 178 359. Several findings on calculator use were noted in this study; in particular, average and low ability students used calculators more often than high ability students. They were used more often on division problems.

Appendix E
Policy Statement on the Use of Calculators on Alberta Education Examinations

Policy Statement

In recognition of the widespread instructional use of calculators in Alberta schools, their relative low cost, accessibility and efficiency in calculations, hand calculators will be allowed for use on provincial examinations at the Senior High School level beginning June, 1980.

The use of calculators on provincial examinations, however, is not mandatory. Students may continue to perform calculations in the usual manner.

Provincial examinations referred to in this policy statement include the achievement examinations and the departmental examinations.

Policy Guidelines and Principles

1. Power of the Calculator

   Calculators should have provision for the following capabilities:

   (a) to perform the four basic operations (addition, subtraction, multiplication and division)

   (b) to compute square root, percentage and the trigonometric functions.

   If a programmable calculator is used, the memory shall be "cleared" before the beginning of a departmental examination using a clear-out key or by other means.

2. Accessibility

   Alberta Education will not supply calculators, batteries or alternative power supplies.

3. Calculator Failure

   Students are advised to take precautionary measures to guard against possible calculator failure during the examination period.