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by

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Calculators, computers, courseware, and manipulative materials are necessary for good mathematics instruction; the teacher can no longer rely solely on a chalkboard, chalk, paper, pencils, and a text. -(NCTM, 1989, p. 253)

Introduction

Teachers today are faced with an ever-changing and growing group of challenges when teaching their students. A continued trend toward the mainstreaming and inclusion of students with special needs into general education classroom, along with the increasing number of students being labeled "At-Risk" have created a demand and necessity for innovative and creative teaching strategies. A somewhat recent phenomenon has been an increased emphasis on the implementation and utilization of "technology" in classroom instruction. Teachers at all levels and all subjects are facing this "push" toward technology, but this project focuses on the teaching of mathematics, particularly at the secondary (grades 7-12) level.

The term "technology" is often associated strictly with electronic or otherwise mechanical devices used to make given tasks easier, more productive, or generally more efficient. Webster's dictionary, however, defines the term technology as "the application of knowledge for practical ends." It is this definition that will used throughout this project, implying that electronic technology, such as calculators,

videodisks, and computer software is only one aspect of the technology that can be incorporated into the mathematics curriculum and instruction.

This project will address the positive and negative implications of the utilization of a number of specific types of technology as discovered through recent research projects across the country and around the world. Practical and applicable suggestions will also be presented for the utilization of technology in the classroom.

Calculators

The use of hand-held, electronic calculators by students as educational tools has been a subject of much debate and research since the mid-1970's when they first became available, practical, and affordable for most students. According to Horton et al. (1992), opponents of the use of calculators argue that:

> "calculators are a foe to instruction because they reduce motivation for learning basic facts, lessen the ability to detect errors, and dramatically change the child's notion of math to thinking that it is mainly pushing buttons on an electric device" (p. 36).

They maintain that calculators decrease or eliminate not only the motivation for students to learn basic mathematical facts and algorithms, but the overall necessity for such skills. According to Taylor

(1980), there exists a fear that "students would become so dependent on calculators that they would lose their ability to compute" (p. 134).

Research, however, has failed to support these fears. In fact, according to Marilyn Suydam, who collected and analyzed hundreds of research projects on the subject, as quoted by Horton et al. (1992):

> "Today, any lingering skepticism among educators concerning the perceived negative effects of using calculators for pencil and paper computations cannot be supported empirically, given the preponderance of evidence that the use of calculators will not debilitate mathematics achievement" (p. 36).

Horton et al., (1992) found that the use of calculators helped to relieve much of the mathematics anxiety and frustration common to many students. Calculators allow the student to focus more on the problem solving aspect of the problem than the computational portion.

> "Overall, the greatest advantage of calculator instruction for school-aged children is the opportunity for them to advance in the hierarchy of arithmetic instruction. . . Functional, multistep story problems become a distinct possibility when computation is no longer a problem" (p. 58).

Crump (1995) claimed, "Using calculators simply speeds the process and creates an air of confidence among the students" (p. 65).

Since research has shown little or no evidence of ill effects on the mathematical abilities of students who use calculators, it would be expected that the majority of American classrooms would have calculators available for student use. In 1990, the National Assessment

of Educational Progress (NAEP) assessed the scholastic achievement of America's students. They found that:

> "technology is far from widespread in American classrooms. Most students have calculators available in the home,, but relatively few have access to calculators in school. In 1986, only . . . 21 percent of the seventh graders, and 26 percent of the eleventh graders reported that their school had calculators for use in mathematical class" (Mullis et al., 1990, p 66).

Taylor (1980) lists a number of factors that may contribute to this rather small proportion of American secondary classrooms using calculators (pp. 143-144). First is the need for curriculum revision. Much of the curriculum developed for mathematics is not conducive to calculator-based instruction. Second, appropriate teacher education has not been widespread. Teachers must be trained and retrained in the use of the new equipment, especially concerning the more complex graphing calculators. Next is the cost involved. While a single scientific calculator may be purchased for under fifteen dollars and a graphing calculator for under eighty dollars, a classroom set of these calculators could increase the cost as much as thirty-fold. Add to this bill batteries, a storage kit, and an overhead version of the calculator for teacher demonstration, and the cost becomes quite considerable, especially for lower-budget school districts. Logistics, the fourth factor listed by Taylor, refers to such things as maintenance, upkeep, and security of the calculators. Fifth, despite the overwhelming evidence disproving the probability of

negative impacts of classroom calculator use, many teachers still fear that calculators will be harmful to learning. The final factor is simply a resistance to change common to a number of teachers. Many of today's teachers learned mathematics without the use of calculators, so they fail to see the need for or the benefits of the utilization of calculators in the classroom. In addition, a considerable amount of additional work is required of the classroom teacher when making the transition to calculator-based instruction. As discussed before, teacher training programs are effective methods of gaining expertise in the use and implementation of calculators, but they require time, energy, and sometimes considerable cost. Likewise, preparing and executing lesson plans are more time consuming due to the necessity of allotting time for instruction of calculator operation.

A number of implications arise from the increased use of calculators in the classroom. First, teachers must analyze and be constantly cognizant of the objective and goals of each individual lesson to consider the appropriateness of calculator use. When the objective of the lesson is to teach basic skills, computation, or a particular algorithm, the use of calculators may not be appropriate. If, however, the focus is on problem solving or discovering patterns and generalizations about numbers, calculators may be a valuable, anxiety-reducing tool for the students that will aid in their discovery of the practicality and

usefulness of mathematics. Marilyn Suydam (1978), as cited by Weaver (1981, p. 159), indicated that at the secondary level, the emphasis on calculator use came in four areas:

> "(1) Calculation, used whenever numbers must be operated with.
> (2) Recreations and games.
> (3) Exploration: because secondary school mathematics teachers' backgrounds are generally good, there is much more of this type of activity than at the elementary school level. In addition, the students who continue in higher-level courses are often more intrigued to explore.
> (4) Use of calculator-specific materials. There is at least one text integrating the use of calculators, with several others being field-tested." (p. 4)

It is clear from the research that calculators, if utilized appropriately, can be a valuable supplement to classroom learning and teaching activities.

Computers

Among the fastest developing educational supplements is computer software. Between 1982 and 1992, public schools spent approximately $2 billion for microcomputers, raising the percentage of American schools having microcomputers to ninety-six percent (Woodward & Gersten, 1992, p. 407). The National Council of Teachers of Mathematics (NCTM) has identified problem solving as a primary focus of the secondary mathematics curriculum. In fact, the NCTM Standards (1989) state, "Mathematical problem solving, in its broadest sense, is nearly synonymous with doing mathematics" (p. 137).

According to Robert L. Mayes (1992), the computer environment has received attention as educational supplement conducive to teaching problem solving skills. Mayes noted that:

> "the project Assessing Cognitive Consequences of Computer Environments for Learning (Mandinach & Fisher, 1983) identified six characteristics of the computer environment which appear to be related to the acquisition of higher cognitive skills: (a) interactiveness, (b) precision, (c) consistency, (d) challenge, (e) complexity, and (f) provision for multiple solutions" (p. 243).

Computer activities promote student participation, provide continuous feedback for the user, and sometimes add a sense of competition with other students as well as past personal performances. Mullis et al. (1990) report that "Students who (use) a computer for problem-solving (tend) to have higher mathematics proficiency than those who (do) not" (p. 67).

Computer software is available for nearly every mathematical topic at every grade level. The graphics and user-interaction capabilities of the computers are constantly improving, increasing student interest and easing teacher instruction demands. Another valuable benefit of computer-aided instruction is the familiarity with computers present among many of today's students. A growing percentage of today's students are raised with a computer present in the home, so the students are more comfortable operating and exploring the computer, and less likely to experience the computer anxiety more common among students

even a few years ago. The so-called "information super-highway" has added a new dimension to the educational potential of computers. The amount and variety of information available through such services as Prodigy®, America OnLine®, and the World Wide Web offer exciting resources for teachers and students. Unfortunately, this capability is such a recent development that research has not been completed regarding the classroom use of this resource.

If computer-based educational activities and instruction offer such positive potential for many mathematics classrooms, why is the average student-to-computer ratio only thirty to one (Woodward & Gersten, 1992, p. 407)? According to Zammit (1992), "[T]he main constraints on the use of computers in schools are inadequate hardware, software, time and trained personnel, all of which are effected by financial constraints" (p. 65). Likewise, Taylor (1980) claimed that "cost has been the most significant factor inhibiting the use of CAI (computer-assisted instruction)" (p. 146). Obviously, adequate funding offers the greatest barrier to wide-spread computer use in the classroom. Even when schools are able to offer an adequately equipped computer lab, the number of teachers and students competing for the use of the lab make it difficult for computers to be used across the curriculum. The expense of hardware, software, and supplementary materials, however has

continued to fall in recent years and the trend is likely to continue, opening the door for even more widespread classroom use of computers.

The cost factor, however, is not the only deterrent to increased utilization of computers in the classroom. As mentioned above, time is also a notable constraint. Like calculators, planning and executing a lesson that incorporates computers requires a great deal of creativity, patience and preparation for the classroom teacher. Time must be allotted for difficulties that commonly occur when students participate in computer activities. The degree to which the students are familiar with the use of computers can vary greatly within a given class, which can result in a variety of difficulties in instruction. In addition, computer knowledge and familiarity varies greatly among the classroom teachers. Teachers must invest time, and often money, into becoming adequately trained in the use of the computer software to be effective instructors themselves. The resistance to change factor among teachers mentioned regarding calculators is also applicable to computers. Most teachers were not educated with wide-spread computer-assisted learning, which can influence their willingness to incorporate computers into their own instruction.

Another time-consuming aspect of computer use is the necessity for the teacher to review and select appropriate and effective software. "[E]ducational software varies significantly not only in quality, price and

applicability to . . . schools, but also in the pedagogical assistance given to teachers to integrate it into a coherent educational program" (Zammit, 1992, p. 65).

Computer-based activities, like calculators, must be used as supplements to learning rather than the basis for daily instruction. An experiment conducted by Mayes (1992) concluded that computer-based may not be the most appropriate method of instruction for all students. He stressed the importance of considering "the number of mathematics courses and the level of achievement in those courses . . . when choosing an environment for the instruction of problem solving" (p. 247). He found that:

> "[s]tudents on the low-mathematics achievement level performed better in a non-computer problem-solving approach. Students on this level may be overwhelmed by the joint problem-solving and computer treatment due to lower initial mathematics knowledge . . . The middle-level mathematics group benefited more from the explicit instruction of a heuristic and strategies combined with the use of the computer as a tool . . . Finally, the high-level mathematics group performed well, regardless of whether the computer environment was applied or not" (p. 247-248).

The teacher must attempt to teach to the educational strengths of <u>all</u> students, which implies, again, that computer-based activities can be a valuable asset to a learning environment if utilized using appropriate materials, frequency, and operating skills of the instructor.

Manipulatives

A term that has quickly become a "buzz word" in the field of mathematics education is "manipulatives." Manipulatives refer to those hands-on educational materials that allow for kinesthetic learning (learning based on "participation" as opposed to hearing or seeing the material) at all levels of education. Manipulatives have been utilized in the primary grades for quite some time, but are now beginning to make their way into the upper level classes. Educators are beginning to realize the value of utilizing hands-on activities as excellent teaching and learning tools.

There are literally hundreds of examples of manipulatives including such things as blocks, dice and spinners, algebra tiles, Miras™, and Geoboards. These types of materials were once considered "toys" which were appropriate only in primary grades, but secondary mathematics teachers have discovered the applications and benefits in their own classrooms. These materials aid in keeping the students involved with the learning process while keeping them interested and on-task. Manipulatives help promote the development of a connection between mathematics and real life activities, bringing relevancy and practicality to the student's learning of mathematics. The hands-on learning promoted by the implementation of manipulatives encourage experimentation and generalization of mathematical concepts. The

NCTM (1991) advocates "tasks that promote the active involvement of all students" (p. 115) When students become active participants in their own learning, they gain independence and improve their self-teaching skills, important characteristics of life-long learning.

Conclusion

The use of all types of technology, from calculators and computers to manipulative materials, in the mathematics classroom has been shown to be an extremely effective teaching technique whose potential and popularity are continually on the rise. The use of these resources is advocated by the National Council of Teachers of Mathematics in their Professional Standards for Teaching Mathematics (1991):

> "Technology is a vital force in learning, teaching, and doing mathematics, providing new approaches for solving problems and influencing the kinds of questions that are investigated. It should play a significant role in the teaching and learning of mathematics" (p. 134).

as well as in their Curriculum and Evaluation Standards for School Mathematics (1989):

> "Technology can foster environments in which students' growing curiosity can lead to rich mathematical invention. In these environments, the control of exploring mathematical ideas is turned over to students. Both inductive and deductive reasoning come into play as students make conjectures and seek to explain why they are valid . . . [T]his freedom to explore, conjecture, validate, and to convince others is critical to the development of mathematical reasoning" (p. 81).

Research, as well, has shown the numerous benefits of incorporating the use of technology into the mathematics curriculum and instruction.

This trend toward the increasing utilization of technology is an exciting development in the area of mathematics for teachers, students, parents, and others associated with and influenced by the condition of mathematics achievement in this country. This presents, however, an important responsibility to the mathematics educators in this country to develop creative, student-involved, and innovative lessons and activities. This may require additional time and training of our teachers, but each minute or dollar spent on the development of an effective presentation of mathematics skills and concepts is an investment in the improved achievement of our students.

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