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The Use of Computers to Enhance Science Instruction in Pre-School and K-3 Classrooms

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The problems with use of the computer for science instruction in pre-school and K-3 classrooms are reviewed. Educators enrolled in the nationally acclaimed Iowa Chautauqua Program have identified and adapted appropriate materials for early childhood teachers and students. These materials use Constructivist and Science/Technology/Society approaches which define more broadly than basic science concepts and process skills. Specific computer programs are identified which coincide with current goals for science teaching. Their use is described and evaluated. The use of microcomputers for science instruction is reported to be successful, useful, and exciting. They have enhanced inservice programs and science instruction for teachers while engaging more students directly.

Computers are technological achievements. And, as such they are person-made objects that can be sources of curiosity, questions, and ideas; they can be used as tools for learning. Such considerations—even for preschoolers—makes their familiarity and use especially appropriate in science. Too often educators and other adults assume that science is what scientists know. Like computers, science seems too abstract and too complicated for early childhood students, especially if it is defined as the explanations of the universe understood and accepted by scientists. Certainly, if science is viewed in such a classical and "school" way, young children can not be expected to conceive of the universe as research scientists do.

Science needs to be re-defined for science education in general —certainly for use as a part of the education for 3-8 year olds. If all persons are to experience basic science (certainly a goal of all science programs, K-12), science must be defined in some way other than the basic concepts describing the universe and the skills that scientists use in developing such concepts. This is the debate between the relative focus on science concepts and processes which has been so common in science education for the past six decades. Probably defining science in only these two dimensions is part of the problem.

Science can be defined as George Gaylord Simpson envisioned it, namely: Science is an exploration of the material universe in order to seek orderly explanations (generalizable knowledge) of the objects and events encountered: *but these explanations must be testable* (Pittendrigh & Tiffany, 1957). Such a broad definition captures all the basic ingredients of science widely accepted by scientists as well as philosophers of science. The definition is a rich one as teaching and learning science is contemplated.

Science is first of all an *exploration* of the universe with the human mind. It requires a person with some curiosity for the objects and events he/she can see and experience. Such curiosity can be seen in all children as a wonderment for the world around us. Basically, all people are curious—some more than others. Unfortunately, the typical school setting seems to discourage such curiosity and the exploration which follows. Instead students are expected to master certain concepts and process skills instead of questioning, wondering, and thinking. It is easy to see why typical school programs discourage this first feature of real science. Results of the National Assessment of Educational Progress in science reveal the alarming fact that interest in science worsens each year the typical student is enrolled in school (ETS, 1988; Hueftle, Rakow & Welch, 1983; NAEP, 1978).

The second ingredient of science is the attempt to explain the events and objects persons encounter as they explore. The formation or creation of such *explanations* is essential for science to occur. It is a phenomenon that is discouraged in most school curricula—especially in traditional science programs. Again it seems that common practice is alien to the basic nature of science. Science concepts and process skills are presented as barriers; without first mastering these, a student is prevented from experiencing the basic ingredients of science. Certainly constructivist learning indicates the *necessity* of each person constructing his/her own meaning. Such construction is basic to science and is probably an essential process to assure learning. And yet in typical science classrooms it is prohibited (Harms & Yager, 1981; Weiss, 1987).

The third and final feature of science is the testing of the explanations that individuals formulate on their own. Explanations—to be science—must be *testable*. It is possible to offer all kinds of explanations—creative ones, ones dependent upon the supernatural, ones that defy experimentation. Such explanations may be appropriate for other human enterprises such as creative writing, art, religion, etc. However, if an explanation of events and/or objects arising from explorations of the universe cannot be tested for their validity, there can be no science experience. Laboratories and hands-on experiences are often justified because experiments characterize science. And yet research reveals that 85% of the laboratories are only verification activities (Lunetta, 1975). There are no real investigations! Children are rarely given the opportunity to test their own ideas and to collect real evidence which supports or refutes them.

Simpson's definition of science which focuses on personal questions, their own possible explanations, and their tests for the validity of their own explanations are basic to the policies of the National Science Teachers Association (NSTA). These features are all central to NSTA's definition for a scientifically literate person and its Position Statement for the decade of the 80s and 90s (NSTA, 1982, 1990-91). Simpson's view of science is also basic to the Science/Technology/Society (STS) approach to science teaching (Yager, 1985). Students are central to the STS approach as they question, try to explain, test their own (and other students') ideas and explanations. Often with the STS approach students use their experiences with science to take action in the classroom, school, community, and beyond. The Simpson definition and the STS approach have been cornerstones for the Iowa Chautauqua Program which began in 1983—just as the intense debates about the use of microcomputers in early childhood education were blossoming (Shade & Watson, 1987, 1990).

The Iowa Chautauqua Program is an in-service model designed to assist K-12 science teachers to reform their science programs. The use of the computer has been basic to this effort. The program consists of several phases, including:

1. A two week leadership conference for the most successful teachers who will become a part of the staff team;
2. a three week summer institute where 30-50 teachers will experience STS as students (while also learning about the use of educational technology, human resources, and new assessment strategies);
3. a week long experience with STS instruction in the school headed by each teacher enrolled;

4. a three-day short course in the fall after teachers have completed their five-day STS experience as they plan for a month long STS module;
5. the four to nine-week STS experience in schools with pre/post assessment data including video records; and
6. a three-day short course in the spring to share results and to assess the general successes with STS in schools.

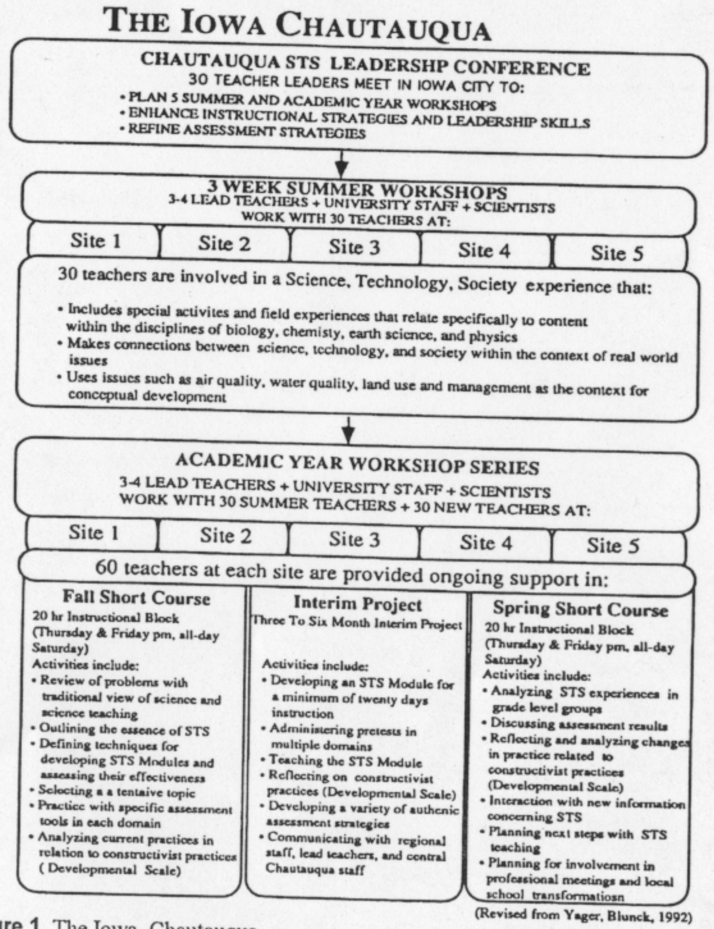

Figure 1. The Iowa Chautauqua

The program seeks to correct the problems of traditional science teaching. It seeks to establish science teaching as a science that includes identifying problems, proposing solutions, testing the proposed solutions, and collecting evidence of the successes. The program seeks to focus upon student learning as opposed to teacher plans for the curriculum.

The Iowa Chautauqua Program includes six domains which characterize STS instruction. These domains represent goal areas as well as areas where assessment information is sought to determine program success. These six domains include:

1. Concept domain (mastering basic content constructs);
2. Process domain (learning the skills scientists use in their work);
3. Creativity domain (improving quantity and quality of questions, explanations, and tests for the validity of personally generated explanations);
4. Attitudinal domain (developing more positive feelings concerning the usefulness of science, science study, science teachers, and science careers);
5. Applications and connections domain (using concepts and processes in new situations); and
6. World view domain (formulating an accurate picture of the nature of science and technology).

Assessment in each domain is determined by the individual teacher to fit his/her specific four to nine week STS module, the age level, and specific objectives in the six domains. *The Iowa Assessment Handbook* describes a variety of instruments that can be used for pre- and post-assessment (Tamir, Yager, Kellerman, & Blunck, 1991). The success of the program can be assessed by a review of the results in terms of changes in teachers and their students. Basically these successes include greater teacher confidence to teach science, greater understanding of the nature of science and science careers (teachers and students), and positive improvement in student 1) mastery of concepts, 2) use of process skills, 3) use of creativity skills, 4) ability to apply concepts and processes to new situations, 5) more positive attitudes toward science, science teachers, and science classes, and 6) more accurate view of the nature of science.

The Iowa Chautauqua Program has included pre-school teachers regularly, even though the focus has been upon more formal school programs, K-9. Some teachers in some schools have developed model modules and activities which illustrate the use of microcomputers in science for early childhood, including pre-schoolers. Early childhood practitioners involved in the Iowa Chautauqua Program are carefully examining the ways that computers can enhance the teaching and learning of science. During the summer phase of the program, the teachers are provided hands-on experiences to overcome fears they may have of the computer and to ensure optimal use of the technology with their students. Even though Iowa has been reported to rank as one of the top ten states in terms of ratio of students to computer, the Chautauqua teachers realize that integrating the computer into the curriculum involves much more than simply counting computers.

The Chautauqua experience provides the teachers the opportunity to examine the issues related to computer use with young children and educate themselves to the promises and problems related to affect practice. Teachers work together to create guidelines and appropriate instructional strategies for integrating the computer into the early childhood environment. Computer specialists, lead practitioners, and teacher participants from across grade levels work together devising creative teaching strategies based upon current research and examples of effective practice. The goal for these early childhood educators is to recognize that the confident and curious teacher combined with creative instructional approaches will result in the most effective use of the computers. The challenge at the pre-elementary and early elementary levels is to help the young learners come to see the computer as an exciting way of exploring their world (Wooddill, 1987)—and that science experiences provide a purposeful context for computer use. The following guidelines created by the Chautauqua early childhood educators during the summer workshops reflect their sensitivity and understanding of the developmental needs of the young child.

- Computers must be integrated into the environment in such a way that the children use them as a natural tools for learning (Shade & Watson, 1990).
- Computers should be integrated across the curriculum relating them to the context of as many activities in the program as possible (Gagne & Merrill, 1991).
- Young children should be provided ample time to test and try the computer. They should be allowed to use the computer in "free-choice" situations and have the freedom to explore either individually or with other students. If done properly, the computer can strengthen children's playful attributes (Shade & Watson, 1990).
- Computers must serve a real purpose; they should help students see relationships, process information, share ideas and stimulate creativity and confidence in young learners (Wooddill, 1987).

- Computer experiences for young children should involve more than drill and practice exercises. Software that promotes active and open-ended explorations should be used whenever possible (Canelos, et al., 1989).
- Experiences with the computer should intimately involve students with the total process. The real excitement of the computer comes with being able to master the technology.

The Iowa Chautauqua teachers are given the chance to test and assess their ideas during the academic year phase of the project. Effective computer-based instruction is closely linked to the teachers' willingness to question, test, and assess new approaches. As the Chautauqua teachers develop their first STS module, they are constantly looking for ways to enhance their constructivist teaching through computer-based learning experiences. The following examples are ideas being tried by early childhood educators involved in the Chautauqua Program.

- Chautauqua preschool teachers are using two open-ended programs that are built upon guidelines that are congruent with the principles of constructivism. These two programs are *The Bald Headed Chicken* (William K. Bradford Publishing Company, Inc., Action, Massachusetts) and *The Princess and the Pea* (William K. Bradford Publishing Company, Inc., Action, Massachusetts). Both programs allow the young learners to create a story/picture. The students choose from a variety of animated graphic figures to fill in the background for a story. The children are encouraged to create a variety of different contexts for these stories. STS teachers are using these experiences to examine the creativity of their students. Teachers are assessing their students ability to create as many different contexts as possible; to make connections within their stories which are unique; to offer explanations for making certain connections and to predict the possible consequences after a certain connection(s) have been made. Teachers are also able to observe their students working in pairs and groups. These teacher observations provide information on the social and emotional development of their students. Students are intrinsically motivated and challenged to come up with a wide variety of ideas. The programs also allow students tho are interested and able to put words with the pictures. Used in this fashion, the computer becomes an object to explore, manipulate, and understand. Chautauqua teachers are beginning to see the many ways that the computer can contribute to the cognitive, social, emotional of the young people they work with in their early childhood classrooms.

- "I Wonder How" questions are generated by kindergarten students working on Apple II computers in Creston, Iowa. The students are spurred to wonder and question the relationships they discover as they explore the world of shapes, sizes, places and directions using *EZLogo* (MECC, St. Paul, Minnesota). Students record their "I Wonder How" questions on a tape recorder as they explore simple concepts related to geometry. The "wonder station" experience provides insight for the teacher into critical thinking processes related to science. Science is built on a strong foundation of curiosity and wonderment. The teachers in Creston use the computer as a tool to develop these attributes in the young learner.
- First grade students in Decorah working with *Dazzle Draw* (Broderbund Co.) create visual patterns and refine motor skills. The challenge for the students then becomes one of searching for these patterns in the world around them. Identifying patterns is a skill that is central to science. Making sense out of one's ideas in relation to the natural world is directly related to one's ability to discern patterns. In the Creston schools, second grade students are also searching for patterns and matching sounds to the real world using the *Stickybear Music* (Weekly Reader Family Software, Optimum Resource, Inc., Norfolk, Connecticut) program. They are challenged to create sounds and invent rhythmic patterns. Students search for similarities and differences in the sounds and then are challenged to match them to sounds they hear everyday. When students identify matching sounds or rhythms, they are recorded by the teacher in the class "sound log". Entries in this log are categorized by the students using a variety of characteristics. Students distinguish between high and low sounds, soft and loud sounds, city and country sounds, day and night sounds. This search for sounds continues throughout the year. These young learners become acutely aware of the noises in the natural world through this ongoing music matching process.
- Third grade students in Carroll are using *Mouse Paint* (Apple Computer, Inc., Cupertino, California) to create the perfect playground. They are expressing their creative ideas and visions for the playground of their dreams. Divided into design teams, students use their artistic and creative talents in putting together a plan for a playground that is "totally awesome" yet safe for all primary people. The computer allows the students to create designs that are more polished in their appearance and intricate in design. Creativity and sciencing go hand in hand.

These students are not only provided an opportunity to be creative, but are involved in a most purposeful manner in solving a problem. The students' designs are considered as possibilities for improving the school environment.

- Early childhood educators in the Sioux City area are discovering the power of the microworld's programs or simulations. Students in first and second grades are using a program called *Beachworld* (Mindscape, Inc., Northbrook, Illinois). This microworld program/simulation relieves young learners of the programming responsibilities connected with *Logo* (Logo Computer Systems Inc., New York) and moves students into the interactive explorations where the student controls the environment (Shade & Watson, 1990). The excitement in terms of science comes in that microworld experiences seem to be intrinsically motivating for students. They stimulate curiosity, questioning, and a sense of control. The goal for the students in this activity is to make a personally meaningful world. In constructing this world, visual and auditory feedback is provided instantly. The concepts that the students are dealing with in this simulation are embedded in a playful context rather than in isolation. These microworlds are open-ended, teacher-designed, child-oriented software programs. Though software of this sort is just beginning to emerge for young learners, the Iowa Chautauqua teachers are positive about the experiences their students are having with these programs.

These are just a few examples of how the early childhood educators involved in the Iowa Chautauqua Program are using computers to enhance the teaching and learning of science. The true excitement for the teachers comes as they have the opportunity in the fall and spring follow-up sessions to learn from one another's trials and tests. The teachers support and encourage one another. They assess the growth and development of their students and monitor the changes in their own teaching practices related to using computers in the science classroom.

Questions regarding the appropriate use of computers in the preschool environment should be considered very carefully. The idea that children are active, curious, and playful in their learning endeavors should be the prime motivator of integrating computer technology into the preschool environment (Swick, 1987, in press). The creation of a developmentally appropriate preschool program depends on the teacher's skill at matching learner needs to the most appropriate software. It should be noted that much of the software being designed for young children is not appropriate

(Knight, 1987). Chautauqua teachers are checking to see if programs promote continuous interaction and that the material and ideas are presented in an interesting, sequential, and creative manner. Experiences for the young child must provide a challenge, stimulate curiosity, and a sense of wonder. These elements when present nurture the development of scientifically precocious students. When used in a developmentally appropriate manner, computer experiences for preschoolers can be more active than television, more dynamic than a picture book, and as open-ended as building blocks, paints, or crayons (Shade & Watson, 1990).

SUMMARY

The use of the microcomputer in pre-schools and early elementary school classrooms has been exciting. There is more interest in science and more student learning. This learning has resulted in students with more questions and better questions. It has resulted in more students with useful ideas/explanations for the questions which characterize their natural curiosity. And, students with the use of technologies like microcomputers are able to generate better ideas and approaches for determining the validity of their own ideas.

The experiences with microcomputers in Iowa suggest reasons for their more extensive use. Of course, this may necessitate more Chautauqua-like programs. Teachers are not likely to rush to the use of computers as tools at any educational level without help and clear evidence of their value. Science builds on new ideas, evidence of the validity of the ideas, and the necessary changes that the valid new ideas suggest. Since, this is "basic science", it is to be expected that the use of the microcomputer and appropriate software should emerge as a powerful tool as reforms in science education are sought.

As advances are made it is important to communicate results. It is only with such communication and weighing and interpreting results that science progresses. This is why we are so anxious to share our results (and those of some exemplary Iowa teachers) with other educators.

Debate has characterized the use of computers in early childhood education for the past decade. Software which matches the needs and competencies of individual students and the teaching strategies known to be effective is only beginning to emerge. The development of such materials—sometimes by the most innovative early childhood teachers and their students—has created a whole new climate for the use of the computer for early childhood instruction. The debate has moved from the appropriateness of the computer as a tool to one of appropriate software for use with the computer.

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Mediational Elements in Computer Programming Instruction: An Exploratory Study

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Sixteen children, 10-11 years old, learned basic elements of a modified version of *Logo* programming under one of two instructional conditions. Both conditions used a general approach called "mediation," but each focused on a different component of the more general approach. Following instruction, children completed several programming tasks. Statistical analyses are presented comparing the two groups. Two case studies demonstrate typical differences between the performance of children who learn under the two conditions. The two cases highlight important differences between the two conditions that should be studied further. Overall results support the continued use and study of "mediational" instruction in computer-based instruction.

There are a number of published studies about computer programming instruction that is designed to enhance the thinking and problem solving performance of children. Several of these studies have documented an important role for an instructional model referred to as "mediation" (Clements, 1986; Clements & Gullo, 1984; Delclos, Littlefield, & Bransford, 1985; Littlefield, Delclos, Bransford, Clayton, & Franks, 1989; Littlefield,