ELEMENTARY SCHOOL TECHNOLOGY EDUCATION

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FOREWORD

Technology education is gaining a new status in our schools. It can deliver increased potential and capabilities to our nation's youth. This is a view currently being delivered to politicians, school administrators, and parents by our professional associations and their members. As a result of its new status, student enrollments are growing nationwide.

Furthermore, enrollments in the Technology Student Association, our technology association for school-aged learners, have surpassed projections through the involvement of elementary-aged students. Elementary students, like other learners, learn better through being involved with materials and tools in solving practical problems they face or becoming engaged through hands-on activities related to their academic subjects. Through this year's Council Yearbook, editors James J. Kirkwood and Patrick N. Foster have presented further insights on technology education in the elementary grades. Through the 46th Yearbook, titled Elementary School Technology Education, the writing teams have further explored the relationship between elementary school technology education and the traditional subjects of the curriculum, reported on methods of implementing elementary school technology education, and described the perspective roles of teacher preparation and inservice professional development activities for promoting elementary school technology education. The editors have sought diverse views and opinions from their writing team members and have melded these into a yearbook which should provide direction for future program development.

In Section I, *Connections—Content and Methods in the Curriculum*, the authors investigate ways in which technology can be interfaced with school subjects such as social studies, mathematics, science, and the language arts. In Section II, Programs—*Technology Education as Process*, the authors investigate engaging learners through the use of their senses in explorations with technology in the quest to expand their memories and enhance their understanding. This is in line with beliefs of the professional associations who represent the academic subject areas. For the past several years, they have been discussing and developing applied activities for their curricula to more fully engage students in their learning. Our authors bring this message to our profession by reporting case studies that have implemented the study of technology for elementary school learners at the local, regional, and national levels.

Finally, through Section III, *Theoretical Considerations*, the authors provide direction for training teachers in our profession, and educators in general, to teach technology to elementary–aged children. Included are chapters on the developmental characteristics of the elementary school aged child, teacher training and inservice education programs, and research on elementary school technology education.

The editors and the Council believe this Yearbook will stimulate thought and guide future research and program development for technology education at the elementary grades. As we prepare students for the 21st century, a century again to be dominated by technology, it is our responsibility to provide educational experiences that engage learners in understanding the technology that they will live and work with throughout their lives. The technology education profession extends its thanks to the editors and authors for the contributions they have made through this yearbook.

John M. Ritz
President, CTTE

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YEARBOOK PROPOSALS

Each year, at the ITEA International Conference, the CTTE Yearbook committee reviews the progress of yearbooks in preparation and evaluates proposals for additional yearbooks. Any member is welcome to submit a yearbook proposal, which should be written in sufficient detail for the committee to be able to understand the proposed substance and format. Fifteen copies of the proposal should be sent to the committee chairperson by February 1 of the year in which the conference is held. Below are the criteria employed by the committee in making yearbook selections.

CTTE Yearbook Committee

CTTE Yearbook Guidelines

A. Purpose:

The CTTE Yearbook Series is intended as a vehicle for communicating education subject matter in a structured, formal series that does not duplicate commercial textbook publishing activities.

B. Yearbook topic selection criteria:

An appropriate yearbook topic should:

1. Make a direct contribution to the understanding and improvement of technology teacher education.
2. Add to the accumulated body of knowledge in the field.
3. Not duplicate publishing activities of commercial publishers or other professional groups.
4. Provide a balanced view of the theme and not promote a single individual's or institution's philosophy or practices.
5. Actively seek to upgrade and modernize professional practice in technology teacher education.
6. Lend itself to team authorship as opposed to single authorship.

Proper yearbook themes *may* also be structured to:

1. Discuss and critique points of view that have gained a degree of acceptance by the profession.
2. Raise controversial questions in an effort to obtain a national hearing.
3. Consider and evaluate a variety of seemingly conflicting trends and statements emanating from several sources.

C. The yearbook proposal:

1. The Yearbook Proposal should provide adequate detail for the Yearbook Planning Committee to evaluate its merits.
2. The Yearbook Proposal should include:

a. An introduction to the topic;
b. A listing of chapter titles;
c. A brief description of the content or purpose of each chapter;
d. A tentative list of authors for the various chapters; and
e. An estimate of the length of each chapter.

PREVIOUSLY PUBLISHED YEARBOOKS

*1. *Inventory Analysis of Industrial Arts Teacher Education Facilities, Personnel and Programs,* 1952.
*2. *Who's Who in Industrial Arts Teacher Education,* 1953.
*3. *Some Components of Current Leadership: Techniques of Selection and Guidance of Graduate Students; An Analysis of Textbook Emphases;* 1954, three studies.
*4. *Superior Practices in Industrial Arts Teacher Education,* 1955.
*5. *Problems and Issues in Industrial Arts Teacher Education,* 1956.
*6. *A Sourcebook of Reading in Education for Use in Industrial Arts and Industrial Arts Teacher Education,* 1957.
*7. *The Accreditation of Industrial Arts Teacher Education,* 1958.
*8. *Planning Industrial Arts Facilities,* 1959. Ralph K. Nair, ed.
*9. *Research in Industrial Arts Education,* 1960. Raymond Van Tassel, ed.
*10. *Graduate Study in Industrial Arts,* 1961. R. P. Norman and R. C. Bohn, eds.
*11. *Essentials of Preservice Preparation,* 1962. Donald G. Lux, ed.
*12. *Action and Thought in Industrial Arts Education,* 1963. E. A. T. Svendsen, ed.
*13. *Classroom Research in Industrial Arts,* 1964. Charles B. Porter, ed.
*14. *Approaches and Procedures in Industrial Arts,* 1965. G. S. Wall, ed.
*15. *Status of Research in Industrial Arts,* 1966. John D. Rowlett, ed.
*16. *Evaluation Guidelines for Contemporary Industrial Arts Programs,* 1967. Lloyd P. Nelson and William T. Sargent, eds.
*17. *A Historical Perspective of Industry,* 1968. Joseph F. Luetkemeyer Jr., ed.
*18. *Industrial Technology Education,* 1969. C. Thomas Dean and N. A. Hauer, eds.; *Who's Who in Industrial Arts Teacher Education,* 1969. John M. Pollock and Charles A. Bunten, eds.
*19. *Industrial Arts for Disadvantaged Youth,* 1970. Ralph O. Gallington, ed.
*20. *Components of Teacher Education,* 1971. W. E. Ray and J. Streichler, eds.
*21. *Industrial Arts for the Early Adolescent,* 1972. Daniel J. Householder, ed.
*22. *Industrial Arts in Senior High Schools,* 1973. Rutherford E. Lockette, ed.
*23. *Industrial Arts for the Elementary School,* 1974. Robert G. Thrower and Robert D. Weber, eds.
*24. *A Guide to the Planning of Industrial Arts Facilities,* 1975. D. E. Moon, ed.
*25. *Future Alternatives for Industrial Arts,* 1976. Lee H. Smalley, ed.
*26. *Competency-Based Industrial Arts Teacher Education,* 1977. Jack C. Brueckman and Stanley E. Brooks, eds.
*27. *Industrial Arts in the Open Access Curriculum,* 1978. L. D. Anderson, ed.
*28. *Industrial Arts Education: Retrospect, Prospect,* 1979. G. Eugene Martin, ed.
*29. *Technology and Society: Interfaces with Industrial Arts,* 1980. Herbert A. Anderson and M. James Benson, eds.
*30. *An Interpretive History of Industrial Arts,* 1981. Richard Barella and Thomas Wright, eds.
*31. *The Contributions of Industrial Arts to Selected Areas of Education,* 1982. Donald Maley and Kendall N. Starkweather, eds.
*32. *The Dynamics of Creative Leadership for Industrial Arts Education,* 1983. Robert E. Wenig and John I. Mathews, eds.
*33. *Affective Learning in Industrial Arts,* 1984. Gerald L. Jennings, ed.
*34. *Perceptual and Psychomotor Learning in Industrial Arts Education,* 1985. John M. Shemick, ed.
*35. *Implementing Technology Education,* 1986. Ronald E. Jones and John R. Wright, eds.
*36. *Conducting Technical Research,* 1987. Everett N. Israel and R. Thomas Wright, eds.
*37. *Instructional Strategies for Technology Education,* 1988. William H. Kemp and Anthony E. Schwaller, eds.
38. *Technology Student Organizations,* 1989. M. Roger Betts and Arvid W. Van Dyke, eds.
39. *Communication in Technology Education,* 1990. Jane A. Liedtke, ed.
40. *Technological Literacy,* 1991. Michael J. Dyrenfurth and Michael R. Kozak, eds.
41. *Transportation in Technology Education,* 1992. John R. Wright and Stanley Komacek, eds.
42. *Manufacturing in Technology Education,* 1993. Richard D. Seymour and Ray L. Shackelford, eds.
43. *Construction in Technology Education,* 1994. Jack W. Wescott and Richard M. Henak, eds.
44. *Foundations of Technology Education,* 1995. G. Eugene Martin, ed.
45. *Technology and the Quality of Life,* 1996. Rodney L. Custer and A. Emerson Wiens, eds.

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CONTENTS

There is comfort in working with children when they are given the opportunity to affect their environment by moving, manipulating and physically changing the forms of materials. Often, in the open and creative structure of a constructional activity, teachers can observe the successes and failures of their students and make use of the teachable moment. In such a relaxed and child-centered environment, teachers can nourish the intellectual, social and physical development of their students.

The discipline of the classroom, however necessary, cannot be allowed to destroy children's creativity, energy and curiosity. All children must be given the opportunity to be problem solvers, to be praised when they are right, to be encouraged when they are wrong, and to be held in respect at all times.

Professionals in the field of technology education have struggled for the past three-quarters of a century to provide elementary school teachers with ideas, resources and inspiration to employ constructional, technological activities to help achieve the objectives of public education in the U.S. This struggle has often been fruitless, but there is a sense that as the twentieth century draws to a close, theorists and practitioners in elementary school education may be ready to listen to what technology educators have to offer.

This volume is an attempt to collect and present the best thinking on elementary school technology education (ESTE) in the United States. It is not, however, a presentation of a single unified view on the topic. To be sure, authors herein present rationales for ESTE ranging from purely educational and child-centered to indispensably economic; some promote ESTE as a subject matter, and others as a method of teaching; and some treat ESTE as a distinct form of technology education, while others prefer an integrated K-12 view.

All of the authors have faith in children and teachers and schools, yet they believe that education in the U.S. needs to improve. The reader is invited to consider how these diverse views can provide elementary school personnel with a range of options to address the needs of all children.

ACKNOWLEDGMENTS

This volume collects the thinking of seventeen of the best theorists and practitioners in elementary school technology education. We are grateful for their creativity and cooperation, without which this effort could not have been undertaken.

Secondly, we thank the members of the Yearbook committee of the Council on Technology Teacher Education who saw potential in our ideas, and the personnel at Glencoe/McGraw-Hill, the publisher of the Yearbook series. We are also indebted to Dr. Karen F. Zuga of the Ohio State University, who provided guidance and advice as we developed the blueprint for this volume.

Finally, we must call special attention to the indispensable work of Julie Gibbs and Michael Kleeberg in helping us fashion a diverse collection of manuscripts into this cohesive volume. Their efforts far exceeded our expectations, especially in bringing focus and clarity to the content of several chapters.

JJK
PNF

Chapter 1 The Child, the School, and the World

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In the light of our present knowledge of the learning process, we must conclude that the surest mode of learning a thing is through experience. We learn what we do and we learn when we do.

Lois Coffey Mossman, 1929 (p. xiv)

The term "learning-by-doing" in educational circles has been used so often that it has become trite. Yet we know children will be more interested, learn more easily, and retain learning longer if they are actively engaged in constructing, manipulating, and experimenting.

Mary–Margaret Scobey, 1968 (p. 11)

Technology is the buzz word right now in elementary education. Everyone wants students to use more technology and teachers to teach more technology. However, most elementary schools do not have a technology education program, and most elementary administrators and teachers don't even realize [what] technology education is.

Terry Thode, 1996 (p. 7)

The more the problems in education change, the more the solutions stay the same. Today, educators in the United States face unprecedented challenges in reaching and teaching children. The general public is barraged with reports of unprepared Kindergartners, gun-toting seventh-graders and illiterate high school graduates. Educators have responded by relating schoolwork with the "real world" and by expanding their repertoire of teaching methods in an attempt to reach more students.

The first of these two solutions often boils down to educating children about their social, industrial, technological world; the second employing hands-on, eyes-on and minds-on methods to teach what used to be taught by recitation and rote. Advocacy of cultural industrial education dates back at least to Rabelias in the sixteenth century; modern notions of using construction and manipulation for educational means were championed two hundred years ago by Herbart. Rabelias and Herbart probably didn't have to face gangs and guns in their schools, but their ideas deserve as much attention today as they ever have.

In the late 1990s, elementary school technology education (ESTE) can lead the way as education and society change in the U.S. At the same time, it can allow children to grow as individuals. As Davidson (1995) notes, "the success of our students in tomorrow's world requires that technology be an integral part of today's curriculum. Unfortunately, this is not the case today" (p. 8).

Clearly, Davidson's words ring true to the technology-education profession, whose members have labored for most of this century to establish industrial education as a central part of the schooling of all children. What isn't so clear is who will be responsible for ESTE. For example, Davidson was talking about *educational* technology, the technology of delivering information, when she said that in order for "students to be successful in this world, they must be facile users of technology. Moreover, they must also know how to maximize the power of technology" (p. 8).

Will the members of the technology education profession be responsible for delivering ESTE? To be sure, technology education will be taught by those who teach it. As Childress and LaPorte (chapter 3 in this volume) and Welty (chapter 6) point out, technological information will inevitably be taught by elementary school teachers as part of science. The same can be said of elementary school social studies. It is too late for the members of the technology education profession to hope to be solely responsible for ESTE. Yet the field of technology education can play a valuable role in teaching children about technology.

ESTE Defined

In this volume, *elementary school technology education* (ESTE) is defined as

> an educational program in which children engage in constructional activities designed to help them learn about themselves and the world around them.

For the purposes of this definition, *technology* is broadly interpreted as the means people use to transfer, transform, transmit, or transport resources to meet human needs. ESTE can be employed by teachers for three basic purposes: to enrich, to deliver, or to reinforce the curriculum.

This chapter will begin by addressing the three most important components of ESTE: the child, the school, and the world. These sections will consider the intellectual growth, physical needs, and social-moral development of children, and will examine the nature of the child's world and school. The chapter concludes with the consideration of how ESTE can help educators address some of the challenges they now face.

THE CHILD

Few will dispute the observation that the most precious resource for the future of humankind is our children. To protect and nurture this resource is the charge of our public schools. The ultimate goal of schools is to prepare every child to live a productive life. Because our world is highly technological, it is imperative that every student be provided insight and understanding of its technological nature. In the process, educators must consider the intellectual growth, the physical needs and rights, and the social-moral development of children.

Intellectual Growth of Children

Benjamin Bloom (e.g., 1985) has pointed out the crucial nature of intellectual development in the child's early years. He notes that from conception to age four children develop 50 percent of their mature intelligence and that from ages four to eight they develop another 20 percent. If intellectual development proceeds as Bloom contends, then formal schooling, beginning at age five, must be content with influencing less than half of the intellectual development of the child, since environmental variations have little effect on intellectual development after age eight.

Hirsch (1987) says the commonly shared information schools need to impart should begin in preschool. "Fifth-grade is almost too late. Tenth-grade usually *is* too late" (pp. 26-27). To teach something in a manner not suited for the age group is, however, as great an error. Rousseau, for instance, recognized the need for appropriate activities in writing about the education of Emile. Curriculum innovators have recognized the importance of constructional activities for the elementary school child but have not demonstrated a full appreciation for the profound effect these activities can have on the intellectual development of the child. They have yet to articulate a planned curriculum that takes advantage of the readiness of the child to learn relevant aspects of technology.

A planned curriculum should not, however, be indiscriminately imposed. The unique nature of each school and the qualifications, aptitude and understanding of each teacher preclude a universally articulated technology education curriculum for the elementary-grades. Curriculum planning for teaching commonly shared technology information must consider the unique personality traits and the intellectual and physical abilities of each child. In such considerations, the curriculum expert is no substitute for the classroom teacher.

Physical needs and rights of children

Today's schools must first address the physical needs and rights of each child and of all children. The school has always valued children; however, of most recent concern is its responsibility for their physical safety and well-being. Although the family has traditionally provided the fundamental safety of the child, in many cases this responsibility has now fallen to the schools. Educators know that a scared and hungry child learns less and that a secure and rested child learns more.

Teachers and administrators must also consider physical similarities and differences among the children when they plan manipulative activities. First-graders, for example, need smaller furniture and tools than sixth-graders, yet the greater variance in physical capability among sixth-graders means that there should be a greater variety of tool sizes available for that grade (see also Trautman, 1989). Because children acquire control first of their large muscles and then of their small muscles, activities should be designed so that younger children use large muscles. First-graders learn to swing a hammer to drive a nail long before they acquire the dexterity to use a screwdriver to drive a screw.

As boys and girls grow, differences between the genders become apparent as well (Shepard & Ragan, 1992). But individual differences often exceed the limitations of popular stereotypes, and opportunities should be provided for all children to exercise their strengths and to improve their weaknesses. Teachers must choose activities and group children to take advantage of these differences.

Social-moral development

Schools must also address the social-moral development of children. This development is now viewed as a phase of growing from immaturity toward maturity. The activity of groups of people is governed by an evolved system of social and moral values, including respect for oneself and for others. These values enable groups of people to behave reliably, justly and with a sense of commitment. An accepted system of social and moral values results in continuity of purpose, pursuit of learning, and moral courage in the face of contradictory behaviors. Public schools have no business teaching religious values. But values that are accepted by all people, such as fair play, cooperation, courtesy and honesty, become important whenever children are involved in cooperative work or play.

THE SCHOOL

For more than a decade, pundits have bemoaned the state of education in the United States. Reports, such as "A Nation At Risk" (National Commission on Excellence in Education, 1983), and popular books, like *Cultural Literacy* (Hirsch, 1987) and *The Closing of the American Mind* (Bloom, 1987) criticize what was perceived as a shift in focus away from traditional values and methods in education.

A decade later, many still view public schools as inadequate. "Every taxi driver—including those who just arrived in America yesterday—and every reporter knows our schools are failures, including those who have never been inside the schools they're attacking " (Meier, 1995, p. 54). As the century draws to a close, however, some experts, acknowledging the shortcomings of U.S. education in the 1980s, believe that public education is improving. U.S. Secretary of Education Richard Riley said, "we are no longer a nation at risk" (1995, p. 3). Berliner and Biddle (1996) note that despite the reduction in real wages in the past 25 years, the increased violence and drug use in school neighborhoods and the seemingly constant criticism public education has received in the past decade, "the overall public systems of schooling [in the U.S.] is much more worthy of praise than of blame" (p. 36). Meanwhile, Bracey (1995) has attempted to "debunk once and for all the notion . . . that there was once a Golden Age of American education from which state we have fallen and must strive to return" (p. 27).

However, others, such as author Hedrick Smith, see more problems than progress. In a recent interview ("Talking with Hedrick Smith," 1996), Smith responded to claims that criticisms of education were exaggerated: "the first reaction is always denial that there's a problem" (p. 32). Still, most agree education is improving. Such improvements are exemplified by innovations in instruction, assessment and educational relevance.

Instruction and assessment

Many educators agree that certain basic skills are necessary for all students. It was this belief that resulted in the popularity of "general education" in the U.S. More recently, it was the adherents of the outcomes-based education (OBE) movement that emphasized the need to establish specific "outcomes" all students would be expected to achieve. Due to several reasons, OBE in the U.S. is now "facing lean times" (O'Neil, 1995, p. 7), although popular efforts such as performance standards and competency-based instruction and assessment share the goals of OBE.

Today, educators in vocational, "nonacademic" fields are also concerned with implementing instructional and assessment innovations that help ensure that meaningful objectives are met by students. For example, they are participating in OBE (Artis, 1994; Luft, 1994), as well as in newer techniques in assessment such as portfolios (Borthwick, 1995), rubrics (Custer, 1996), and standards-based performance assessments (Custer, 1994; Rabinowitz, 1995). Their efforts are extending into the traditional academic areas, where teachers are also increasing the use of portfolio-based evaluation (see Ross, 1996) and other such techniques.

The need for bringing meaning to the classroom

A related concern is the increased need for motivating students. As Maselow (1995) notes, "kids who are motivated and excited—learn" (p. 58). And while motivation leads to learning, the literature suggests that relevance of subject matter leads to motivation. Engaged students are attracted to schoolwork, persistent despite obstacles and visibly delighted by the resultant accomplishments (Schlecty, 1994).

To English teacher Lynda Gillespie (1995), "The truth is that for education to have value—for it to be meaningful and stick in the minds of our students—it must be relevant" (p. 78). Pahl (1995) reminds us, relevance is often not the case. "Research has confirmed a problem often pointed out by our students—that too many names, dates, and facts can make social studies boring and irrelevant" (p. 154).

Students who want to know why they have to learn something may be earnestly looking for relevance in their education—they're not simply complaining (Christ, 1995). So why do they have to learn this? "The typical reply goes something like this," Parnell (1996) suggested, "because you might need it someday" (p. 18). To Parnell,

> that familiar reply is woefully inadequate. Not only does it represent an approach to education that is failing to reach the large majority of our students, but it also tends to ignore

> the fundamentals of how the human brain makes connections and processes knowledge (p. 18).

Making elementary school learning meaningful has been advocated by educators in traditional academic fields (e.g. Olsen, 1995), as well as by technology educators (e.g. Thode, 1996). Kleeberg and Kirkwood, in chapter 5 of this volume, describe how the appropriate use of children's literature can bring increased meaning to the classroom. Additionally, in chapter 7, Todd discusses how innovative programs can motivate students through rigorous and authentic student-centered experiences.

THE WORLD

Technology has spawned positive and negative societal influences on society that affect the way children learn. Communication technology is more readily at our disposal today then ever. As Fred and Helen Ilott discuss in chapter 4 of this volume, the impact this increased access has on children is marked. Dixon claims that "more than anything else, it was direct access to information that allowed children to sprint past schooling and get out in front: first mass-market print, then movies, then radio, then television, now computers" (1994, p. 362). Since technology is changing so rapidly, the teachers of our children must develop their own understanding of technology and pass this self-taught information on to their students. As peoples' use of technology has changed the world, it has also reduced the influence of significant institutions and cultures on our lives. Generations of children are different because of these changes. Dixon notes that "dozens of other momentous changes speeded the redefinition of childhood in this century: wars, mass migrations, changes in the status of women and minorities, the pop explosion, family breakdown, democratization of institutions other than schools, cycles of boom and bust, and so on" (1994, p. 362).

Children at Risk

While faults and praises of the school system wax and wane with the latest reports of accepted and self-proclaimed experts, there are very real problems children bring to the schools. These problems include urban poverty, family upheavals, displacement of familiar social institutions and other social ills too numerous to recount here. These facts of contemporary life affect not only children, but teachers, schools, and teacher-preparation institutions as well

The children who now populate our schools are different in many ways from their predecessors. These differences affect the things children know when they enter school, the way they behave in school, the manner in which they learn, and the ways in which curriculum and methodology must change to provide for their needs.

Family makeup Perhaps the most-cited demographic factoid about today's schoolchildren is that more and more are coming from single-parent families. Research indicates that children from two-parent families have higher-grade-point averages, better attendance records, and more positive behavioral ratings than those from reconstituted and single-parent families (Featherstone, et al., 1993). Parish's (1990) research on children with divorced parents reinforces this contention.

Compounding the difficulties faced by children from single-parent families is the fact that teachers' perceptions of the effect of single-parent families can prejudice their evaluations of students. In one study, Israeli teachers evaluated a fictitious fifth-grade boy who was described as being from various family backgrounds. Teachers expected the child from the intact family to function better academically, socially, and emotionally (Guttmann & Broudo, 1989).

Barriers facing members of minority groups Neither differences in individual background characteristics nor variation in ability-group assignment alone explain why African-American children learned less than Caucasian children in a 13-class study of 302 first-graders. To account for the differences, Dreeben and Gamoran (1986) looked at a set of instructional conditions, primarily time spent in instruction and the coverage of curricular materials. These features differed in schools attended by African-Americans and by Caucasians in this study, with African-American students being exposed to restricted learning opportunities originating in district and school differences in the availability of technological resources. The findings of Thompson et al. (1988) confirm that differences in achievement scores between minority and nonminority students are accurately attributed to a wide variance in educational opportunities.

Factors such as minority status and the number of adults in the home can statistically be linked to socioeconomic status, which is considered to be the most important predictor of school performance. In a two-year study of first-graders' mathematics achievement, the most important sources of variation in math achievement were school segregation and differences in family socioeconomic status (Entwisle & Alexander, 1992). In general, family stability, regardless of the form of the family, was associated with better school performance in another 1992 study (Weisner & Garnier).

Diversity is reality Teachers must accept and teach the children in their classrooms. The children may come from single-parent or two-parent families, may be rich or poor, may or may not receive parental support and guidance and may be affected by social ills such as domestic violence or drugs. For all practical purposes these conditions are beyond the power of the teacher to effect. The schools of today are attempting to cope with these problems. "Nobody is content with the state of urban public schools, least of all the people who work in them. When asked to envision the kind of school they want, teachers describe much more orderly, focused, and collaborative working environments than they currently encounter" (Hill, 1994, p. 396).

ELEMENTARY-SCHOOL TECHNOLOGY EDUCATION

ESTE can play a role in improving the lives of all children. This improvement goes beyond simply knowing about technology. The very nature of an activity-centered curriculum places a teacher in the role of facilitator rather than of a didactic presenter responsible for all the behavior of the children in his or her charge. In an integrated technology education activity, especially one that requires cooperation and collaboration and results in tangible products, the teacher can immediately see how each child is faring with a problem. Often, using one-on-one instruction—sometimes shoulder-to-shoulder instruction—the teacher cannot help but begin to develop a better realization of the way each child is developing manual dexterity, processing information, learning values, and developing understanding.

Barbato (chapter 8 of this volume) and Wright and Miller (chapter 9) discuss how ESTE can also help children *construct* their own understandings of the world around them. Although sometimes viewed as a new educational trend, *constructivism* is far from a fad. Wirth (1993) argues that as we adopt participative styles of management in post-industrial education, "we need to adopt active, constructivist learning for students as a central goal for schooling . . . Such efforts are not unlike those that are helping to revitalize American industries and would tap the core values of the American democratic tradition'' (p. 366).

ESTE in the School

"Constructivism" is not the only new word in the vocabulary of educators. In fact, a wide variety of solutions has been suggested for the challenges faced by teachers and schools. The field of technology education appears to be in a unique position to make practical many of the solutions offered for educational woes, yet technology education has not been widely practiced in elementary schools. Meaningful claims are being made by teachers about the benefits of ESTE, but as Zuga points out, in chapter 12 of this volume, these claims have not been substantiated.

There is currently an abundance of conceptions of, and confusion about, the role of the field of technology education in U.S. schools (Raizen, Sellwood, Todd, & Vickers, 1995). But consensus is building that education about and with technology is essential for all children (Satchwell & Dugger, 1996). To many technology educators, this consensus is a clear mandate for the inclusion of technology education in public education. "Someone must meet the challenge of preparing all citizens to live in a highly technological society," Loepp (1992) writes, arguing that the technology education profession is "in the best position to meet the challenge" (p. 20).

Still, there is the sense that in order for technology educators to have an impact on the education of all children, the field may have to work with professionals in established fields of education to negotiate a place for technology education (Sanders, 1996), including at the heretofore overlooked elementary school level.

Technology education as it relates to other educational programs Teachers' associations representing nearly all fields of education have released "standards documents" designed to position their fields as important or essential to the education of all children. Technology education objectives are compatible with many of the objectives in these documents (e.g., Pucel, 1995). At times, academic objectives are nearly identical to those held by technology educators, especially at the K-4 level. For example, to many in the field of fine-art education, elementary school students should "know the differences between materials, techniques, and processes" and "develop new techniques, approaches, and habits for applying knowledge and skills . . . to the world beyond the school" (Consortium of National Arts Education Association, 1994, p. 33) This statement has much in common with a typical goal of technology education: "at all levels, the program/course content for technology education should be based on . . . applying tools, materials, processes . . ." (Savage & Sterry, 1990, p. 26).

Popular objectives in the field of social studies also point to the need for technology education at the K-4 level. The following statement from the National Council for the Social Studies (1994) is representative.

> Young children can learn how technologies form systems and how basic technologies such as ships, automobiles, and airplanes have evolved and how we have employed technologies such as air conditioning, dams, and irrigation to modify our physical environment. (p. 28)

To economics-education professionals, students should know that "technological change depends heavily on incentives to reward innovation . . . technological change and improvements in a society's productive resources promote economic growth" (Saunders & Gilliard, 1996, pp. 64; 75). Similarly, according to the Geography

Education Standards Project (1994), "the geographically informed person knows and understands . . . the process, patterns, and functions of human settlement . . . (and) how human actions modify the physical environment" (pp. 22; 24). Cynthia Szymanski Sunal and Dennis Sunal employ chapter 2 of this volume to discuss in detail the connections between social studies and technology education.

Technology education has many objectives in common with established subject-matter fields in the arts and humanities. These objectives often have a longer history as technology education goals than as academic goals. Similarly, signals from the mathematics and science education communities also suggest that the goals held by these traditional subject-matter fields are related to those held by technology education.

The National Science Board Commission on Precollege Education in Mathematics Science and Technology (n.d.), for example, recommends that "attention should be directed, to the degree appropriate for each grade level, to questions of how people—as individuals and their aggregations into nations—contribute to technological change and how people are affected by it" (p. 62).

In an often-cited report from the American Association for the Advancement of Science, Johnson (1993) wrote that "to live a fruitful and rewarding life in the twenty-first century will require a knowledge of technology and society learned from historical example, contemporary illustrations, and informed prognostication" (p. 12). Childress and LaPorte suggest in chapter 3 of this volume that information about math, science and technology may be treated jointly at the elementary school level.

An increasingly popular view of ESTE in the U.S. is that technology education is design education (Todd & Hutchinson, 1991)—a characterization often regarded as having originated in the UK and elsewhere, not the U.S. In the National Research Council's (1996) *National Science Education Standards*, it is suggested that "children in grades K-4 understand and can carry out design activities....In grades K-4, children should have a variety of educational experiences that involve science and technology, sometimes in the same activity and sometimes separately" (p. 135). Todd also discusses design technology In chapter 7 of this volume.

ESTE in the Classroom

Among the latest innovations in curriculum and teaching, there are a few that particularly affect the role of ESTE in the classroom. First, subject-matter integration seeks to unite the curriculum in a theme-based format. This is not a new phenomenon, but the emphasis is new, and the research that supports this innovation reinforces the argument that ESTE could become an appropriate organizer for many thematic units taught in more traditional ways. Second, cooperative learning, or its more carefully described correlate, collaborative learning, has been widely disseminated in educational circles. Technology activities in the elementary school classroom are usually cooperative activities, and research suggests that collaboration yields unexpectedly favorable results. Finally, the role of hands-on activities in teaching abstract concepts is being discovered by more and more teachers and researchers. Examples can be found in mathematics, science, social studies and language curricula.

Subject-matter integration Kieft (chapter 10 in this volume) and David (chapter 11) discuss ESTE in elementary school teacher training, pointing out that ESTE is not part of teachers' education and therefore is unlikely to be part of the education they offer to the students in their charge. However, technology is in the curriculum, no matter what the viewpoint of the teacher may be (Foster & Kirkwood, 1993). ESTE is evident in the social-studies unit where children learn about life hundreds of years ago in Cameroon by making models of Cameroonian homes, reading traditional Cameroonian stories, arranging their model homes into a village, and cooking and eating cassava. ESTE is evident in the math unit in which first-graders hammer nails into boards to simulate shapes, share their experiences in a class publication, and hammer and share some more. ESTE exists in all of the traditional school subjects and often remains there, isolated and foreign. Although awareness about ESTE is growing, it is the rare teacher who makes a conscious effort to draw together the disparate subject matter to teach technology concepts (Ortega & Ortega, 1995).

In his overview to the first section of this volume, Wright mentions the fourth-grade teacher who is teaching about clothing, transportation and shelter in her Missouri history unit, yet doesn't feel as if she is teaching her students about technology. The truth is that "technological awareness is currently woven in an unidentified pattern in the school system, but rarely is there a conscious effort to draw together an understanding of the immense effects of technology on our lives" (Ortega & Ortega, 1995, p. 12).

Braukmann (1993) notes that technological activities have a place in the classroom; it is up to the teacher to provide opportunities to use these in collaboration with the established curriculum. Willis (1995) cites examples of interdisciplinary units in his *Education Update* article. All of these units have technology as their focal point. The first problem the children studied involved the school building itself, which was designed in the early 1970s as "open space," and had subsequently been remodeled to form rooms. These rooms were either too hot or too cold. The students studied the school's heating, ventilating and air-conditioning (HVAC) system, developed proposed solutions, discussed them as a class and presented the best one to the administration. Another project involved the students in a study of the problems associated with the local drinking water. In investigating practical, interdisciplinary units, Willis (1995) found that young students are capable of addressing problems beyond what is traditionally expected of them. The attitudes and skills they develop will enable them to make informed choices as adults.

Integrated ESTE activities enable students not only to develop motor skills but also to exercise their mental processing of ideas and problems, which can also give them knowledge of materials and technological processes. Such knowledge, skill, and aptitude enable these youngsters to engage in advanced problem solving in the upper grades (Ortega & Ortega, 1995). Integration also increases student interest. When engaged in integrated technology education activities, "children are more attentive to their learning, achieve a deeper insight or meaning of the concepts, and are able to apply the information to realistic situations" (von Eschenbach & Ragsdale, 1989, p. 225).

Collaborative Learning Activities If the teacher's goal is to have the students learn more information, form greater insights, or learn more quickly, then organizing collaborative groups should be considered. Thousand et al. (1994) compared cooperative with collaborative learning. They found that cooperative learning is more structured, more focused on specific behaviors and gives rewards while collaborative learning focuses on interdependence (a key word) and individual accountability. Quite frequently, cooperative groups produce work that could easily have been done by a single person. Someone once said that a camel was a horse designed by a committee which, of course, is a "cooperative" group—with widely varying degrees of cooperation. When students are grouped according to different talents and abilities, they are collaborating—bringing different viewpoints, attitudes and abilities to bear on the common problem. This kind of cooperation creates solutions that go beyond the abilities of a single person.

When a group consists of students with varying talents and ability levels, the students seem to balance one another out for better understanding. In comparing pairs (dyads) of high achievers with dyads of low achievers, Bracey (1994) reported that the high-achieving dyads mutually reinforced learning, while low-achieving dyads mutually extinguished learning, but that high-low dyads "were beneficial to each member in a different way" (p. 255). He theorizes that the high-achieving students were led to better conceptual understandings and that the low-achieving students "learned useful skills from modeling" (p. 255).

A rich picture of some important dimensions of cooperative small group instructions emerged from a study by Mulryan (1995). The study compared high- and low-achievers in mathematics as perceived by teachers and students in small group instruction. The study concentrated on student thought processes and found that "lower achievers can benefit by having mathematics content explained to them in a way that is sometimes more comprehensible to them than the teachers' explanation" (p. 283). Gamson (1994) says that learning is influenced both by the content and the activity in which it occurs and that some students learn more effectively in groups than others. This study shows that teachers must identify the learning styles of their students and structure their participation in activities accordingly. Gamson (1994) notes that collaborative learning requires the overcoming of certain old power relations among students and teachers.

Char (1991) studied students who were learning collaboratively as they used both physical manipulatives and computer simulations. Char concluded that collaboration among students improved learning. Note that while the activity was not specifically a technology education activity, it did involve the use of physical manipulatives.

Problem-solving activities usually involve research by group members. Jongsma (1990) says that collaborative research activities are especially useful in stimulating students. Kim notes that "the work of Vygotsky and others has shown that children's ability to construct knowledge is facilitated in an environment where learning is based in a social context" (1994, p. 2). Kim also gives credence to the idea that activity-based collaborative learning is important. "Children's learning is . . . facilitated when they are able to use a wide variety of materials in a wide range of activities and in cooperation with adults who help them ask good questions" (p. 21).

ESTE activities are often designed to be integrated, as noted above. When the curriculum is integrated, students often work together to solve common problems (Stone, 1987). Technology activities by their very nature allow children to use a wide variety of materials and to engage in a wide range of activities. Avery et al. (1994) looked at collaboration between vocational and academic teachers and noted that such cooperation "injects authenticity into the lives of students, many of whom have had no exposure to the connection between real life and recorded event . . ." (p. 272). Strategies invoked by collaborative groups in solving technology-related problems often provide an authenticity that is impossible otherwise.

Concrete learning The educational literature is replete with discussions of the benefits of having children work with their hands while they learn. Often this discussion is held in the absence of any recognition that these benefits have been known for centuries. Almost never is it recognized that ESTE represents the legacy of these centuries of practice and research (see Kirkwood, 1994).

Today, "hands-on" methods appear to be gaining popularity in mathematics education—albeit slowly. Hatfield (1994) found that the use of math manipulatives among 106 elementary school classroom teachers was "limited" and found "a pattern of diminishing use" as students got older (p. 303). At the elementary-school level, mathematics is increasingly, if slowly, being taught with the aid of hands-on methods. Anderson (1994) described projects in which mathematics was taught through a unit on package design and construction. "These projects reflect the higher order thinking and worthwhile mathematical tasks" emphasized in the National Council of Teachers of Mathematics' standards, including "the goal of 'mathematically literate workers' and the illustration of 'utility and value of mathematics' for solving everyday problems" (Anderson, 1994, p. 150).

An interesting rationale for math manipulatives has been described by Bohan and Shawaker (1994) where they define the concept of a "bridge" stage between concrete manipulative experiences and the resulting abstract learning. This stage can take place, for example, in computer simulations of concrete experiences, such as sorting and grouping of sizes and shapes first with wood blocks and then with computer images. Manipulative experiences are better than workbooks. They allow children to experiment and to teach others (Stone 1987).

In the field of social studies, "object-centered learning has had a time-honored connection with the social studies and with young children" (Field, Labbo, Wilhelm, & Garrett, 1996, p. 141). Usually, this object-centered learning involves students handling but not changing materials. Rule and Sunal (1994) described an activity in which they had students arrange artifacts; Hatcher (1992) had students create their own "artifact kits" (p. 267) as part of an activity in which students demonstrated their understanding of social-studies principles. "No picture [in a textbook] can substitute for the experience of handling an object or viewing it in three dimensions," she argued (p. 267).

The use of hands-on methods can lead to increased—and increasingly meaningful—student self-expression. Student creativity, Sternberg (1995/1996) wrote, "requires the application and balancing of three types of abilities—the synthetic, the analytic, and the practical—all of which can be developed" (p. 80). He elaborated:

> Synthetic ability is...ability to go beyond the given to generate novel and interesting ideas...Analytic ability is...the ability to analyze and evaluate ideas, recognizing the good ones, working out their implications, and perhaps testing them. Practical ability is the ability to translate theory into practice, to abstract ideas into practical accomplishments. (p. 80)

It is just these kinds of skills that are fostered by technology education (Wright, 1992). At the elementary school level, "learning through the study of technology provides an opportunity to meet varied student intelligences and learning styles" (Hill, 1996, pp. 22-23).

Science, of course, has nearly always been activity-based in the elementary schools—when it has been practiced. Perry and Rivkin (1992) show how science manipulatives should be used to allow children time to "mess around," to observe and record data and to summarize through graphing and drawing. They state, however, that messing around has a purpose and shouldn't be considered play. Goldhaber (1994) uses "transformational materials," such as ramps and pulleys in science activities with elementary school children. Goldhaber believes that although the use of such materials appears to be play, and therefore nonacademic, the success in teaching science using these activities makes a good argument for their use in abstract learning.

There are at least four levels of hands-on learning (Foster, 1995): handling, manipulation, assembly and construction. *Handling* is the lowest level of concrete learning and is exemplified by children petting a rabbit during a unit on mammals or touching a toy made for or by children in Japan. *Manipulation* is when children arrange objects into patterns—such as wooden blocks with painted letters ordered in a sequence to spell a word. In *assembly* activities, children make something new from pieces they put together then take apart. A Lego® house and an Erector®-set car are examples. Finally, *construction* engages the children in physically and permanently changing the forms of materials to create something new. Fourth-graders are involved in construction when they make a wooden xylophone by cutting dowels to size, drilling holes in them and nailing them to a wooden frame. They have created a technological artifact.

CONCLUSIONS

Educational reformers call for children to have an increased understanding of the rapidly changing world around them, but traditional fields of education are at a loss to provide it. Teachers know that groups of children learn better when they work with their hands toward a common goal, yet find it difficult to devise concrete, collaborative activities that actually help achieve the sometimes abstract objectives set by principals and school boards.

As more and more of these objectives are added to report cards across the country, teachers must spend less and less time focusing on what really matters in education—the child. Thus activities become teacher-centered, not student-centered. This model becomes progressively less effective as the students entering today's schools become progressively more diverse.

The more things change, the more elementary schools need ESTE. As the authors in this volume demonstrate, it is ESTE that can provide a context for children to learn about their world in a hands-on, constructive manner. It is ESTE that can facilitate subject-matter integration and help teachers and students efficiently meet objectives. And, properly employed, it is ESTE that can allow the individual student to grow, to celebrate his or her individuality and to learn to get along with others by accepting challenges truly designed to prepare him or her for the future.

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Section I

Connections: Content and Methods in the Curriculum

OVERVIEW

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The children were particularly rambunctious on that Tuesday afternoon in September as they boarded the bus for home. After all, it was the first day of school. And it was over. The fourth grade teacher was relieved that things went so well with her new students. As she finished up a bit of paperwork, her guests—technology teachers from a nearby university—looked around the newly-redecorated room. One wall of the average-sized, fourth-grade classroom was covered with posters about pioneer life in Missouri. Different scenes were depicted: a farmer plowing a field, teams of men building a log house, women cooking on wood-burning stoves and men felling trees with axes and saws. Noting her guests' averted attention, the teacher mentioned that the first theme of the new school year was pioneer life in Missouri. The second theme was deserts. She wondered out loud how to make the transition smooth and seamless between the two.

To the technology teachers, the answers were somewhere in the classroom—or, perhaps more correctly, they were everywhere. Many of the desert-theme posters and the entire Missouri-pioneer wall depicted people engaged in technological activities or using technological products. One technology educator began posing questions. How would desert-dwellers build a home? What materials and tools would they use? Would they be similar between the Sahara and the American Southwest? What productive activities would desert-dwellers be engaged in? How are people's lives affected by their geographical location, and how are technological developments thus affected? All of this raised another question: how could all of these social-studies and science ideas be drawn together? The three educators sat down at a bank of fourth-grade desks and brainstormed. Perhaps students could research the natural resources available in each region (social studies connection), and the types of materials available to build a home, and the tools that existed at that time. Then they could design and construct scale models of typical homes from appropriate materials. The teacher could use thermal insulation from both heat and cold as a logical first connection with science, and units of measurement as an identified content area for fourth-grade mathematics. As a natural link with language arts, the students could answer short essays to describe the research they have done and read books about people (particularly children) in each region and how they lived. The idea underlying all of these activities is technology. Not just computers but technology in all its forms. The fourth-grade teacher had long been teaching technology, but only now saw how it all fit together. She bid farewell to her guests and sat down at her desk. This day was turning out to be the start of a great year.

CALLS FOR TECHNOLOGY EDUCATION

It is imperative in today's technology-based societies that all students become technologically literate (Dyrenfurth & Kozak, 1991; Raizen, Sellwood, Todd & Vickers, 1995). Many national reports on the status of education in the United States have called upon schools to provide increased experiences with technology and focus on technological literacy (see, e.g., Johnson, 1989; AAAS, 1989; TEAC, 1988; Technology for All Americans Project, 1996). Common sense indicates that this focus cannot be accomplished in a single middle school course. Indeed, an understanding of technology and its social impacts and consequences should begin as soon as students begin attending school. All students, regardless of socioeconomic level, race, ethnic background, home community or disabilities, need to be able to cope with change, identify and solve problems. They will need to employ their education for success at work and in further education. All students, then, need elementary school technology education (ESTE).

Content, Process or Constructive Methodology?

ESTE may be viewed from at least three different perspectives: as *content*, as *process*, or as a *constructive methodology*. Each approach has value and contributes to the development of children, but their underlying philosophies are quite different. Philosophical considerations are important because they determine not only the nature of the ESTE instruction but also the palatability of a new educational program to teachers and administrators as well.

In the *content* approach, technology is viewed as a unique body of knowledge. ESTE would have dedicated classroom time during the day or week, and, like the content areas of science and social studies, it would probably be added as a subject on the report card. In the *process* approach, ESTE is viewed as a process of creating, designing or modifying one's environment. Children would be engaged in semi-structured activities focused on the "how and why" of technology rather than on the "what" as in the content approach.

In both the *content* and *process* approaches to ESTE, technology is the primary focus. From the *constructive methodology* standpoint, ESTE is a method for teaching other school subjects. Advocacy of this approach implies two beliefs: (a) children will learn the other subjects better, have more fun and be more motivated via ESTE and (b) technological content and processes will naturally be learned while students are doing constructive activities. Experience suggests that student interest in learning about technology cannot be stifled, even when the focus is initially on other subjects (Wright & Foster, 1996).

Ideally, a complete study of technology would include both the content and processes of technology. But the constructive-methodology approach is the most plausible method of introducing ESTE—at least as a first step. Elementary teachers are already dealing with overflowing schedules. Adding a new content area to elementary school classrooms is not likely to succeed in the immediate future. There is considerable consensus (Foster & Wright, 1996) that ESTE can serve as a *constructive methodology* to teach other school subjects. No single subject area in the elementary school is better positioned to serve this function. ESTE has the unique ability to help integrate and provide relevance to the elementary school curriculum.

Connections

The connections between ESTE and the traditional subject areas of social studies, science, math and language arts will be discussed in section I of this volume, with specific recommendations and sample activities to accomplish seamless integration.

One form of subject-matter integration discussed widely in the educational literature is the integrated teaching of mathematics, science, and technology. In chapter 3 of this volume, Vincent Childress and James LaPorte provide a thorough discussion of the topic. The need for ESTE to provide a context for the study of science and mathematics is well documented, and Childress and LaPorte describe the nature of integration of the curriculum, as well as the role that technology education can play in this process. They assert that now is the time for technology education to become essential learning for all students. In their opinion, essential learning includes the content of technology, as well as the technological process of problem solving, as a means to connect mathematics and science to the world outside the school.

In chapter 2, Cynthia Szymanski Sunal and Dennis Sunal discuss ESTE as a social study. Social studies considers people, their societies and the mutual impact of technology and people. The teacher, these authors believe, plays an important role in helping students understand the relationships between people and technology. They describe five major goals of social studies: concepts, generalizations, process skills, values, and attitudes. All of these goals can be delivered with the help of ESTE. To Sunal and Sunal, technology is frequently an instigator of or a vehicle for the social actions individuals take. Thus ESTE can foster children's involvement in social action. Further, students who study the history of technology may understand that technology has always been a part of human society and has, to a great extent, defined the characteristics of human societies throughout time. To Sunal and Sunal, technology and society form a "great connection." One does not exist without the other. Indeed, they assert, the world is one integrated experience. Given this, shouldn't the curriculum that studies the world be integrated also?

In the fourth chapter, Fred and Helen Ilott suggest that language mastery and the acquisition of technical understanding have something very important in common: both are fundamental to children's construction of knowledge from the contexts in which they live. Language implies content—experiences, ideas, and questions that require language for their expression. Technology can provide excellent content for powerful language-arts activities that combine both manipulative experience and language. Children can fuse experience and language in the process of cognitive development. Expanding experience into the realm of technology provides new ideas, structures and functions in which to extend previously developed language.

Similarly, Kleeberg and Kirkwood, authors of chapter 5, focus on the integration of children's literature and ESTE. It is believed that children are active "meaning makers," that they are always interpreting and making sense of their world from what they have learned and observed and continue to restructure as they learn more. Language must be used in a social context to make meaning and must be expressed through language patterns. Through social action, knowledge is organized, constructed and changed as additional experiences occur. In essence, our knowledge and view of the world is changing daily as we live our lives. Language allows us to organize and express our views and, as such, contributes to this development.

Ilott and Ilott (chapter 4) demonstrate that among the other advantages of combining language arts and technology education are the "authentic" nature of the experience for reading and writing and the opportunity to reduce gender bias at an early age. The key to a successful integrated language arts-technology education activity, they suggest, is allowing both technology activities and language development to prosper in unison. In such an environment, some of the most teachable moments arise spontaneously. Surely, these moments are one of the things that makes teaching so rewarding!

CONCLUSION

The current push for content integration is evident throughout educational literature in general. At the elementary school level, this integration is largely happening through a thematic approach. Too often in technology education, educators think of "integration" as only concerning math, science and technology. But as the authors in this section demonstrate, integration involves all subjects in the elementary school curriculum. Several strategies, in the context of constructivist learning theory and the spiral curriculum, are presented in this section to make this integration a reality in the classroom with ESTE as the medium.

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Chapter 2 Technology as a Social Study

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Technology is a pervasive part of our social world and has a diverse impact on people in all types of societies. No society is technology-free, for humans are tool-users. Social studies considers people, their societies and the mutual impact of technology and people on each other. Teachers have a pivotal role in helping students understand the relationships between people and technology, especially in the social studies arena.

SOCIAL STUDIES AS A CURRICULUM AREA IN THE ELEMENTARY SCHOOL

Social studies derives its goals from the nature of citizenship in a democratic society and from a society's links to other societies. It draws its content from the social sciences—anthropology, economics, geography, political science, psychology, sociology, history and other disciplines. Social studies also draws its content from the personal and social experiences of students and from their cultural heritage. It links factors outside the individual, such as cultural heritage, with factors inside the individual, particularly the development and use of reflective thinking, problem solving and rational decision-making skills, for the purpose of creating involvement in social action. Social action is a continuum of possible activities ranging from single efforts requiring small commitments of time and talent to long-term projects requiring a regular commitment of time and multiple intellectual and social skills (Sunal & Haas, 1993).

There are five characteristics that describe what occurs as students learn about social studies. First, students are involved in a search for patterns in history. A pattern is a regular activity that has occurred in the past and can be expected to occur again in the future. The world is full of patterns; common expressions reflect historical patterns in such phrases as, "past events influence future events" and "new technologies are more quickly accepted in some societies than in others."

Second, social studies involves students in both the content and processes of learning. People use process skills, such as observing, inferring, and hypothesizing, to make sense out of their experiences (Michaelis, 1992).

Third, students are involved in information processing when they learn about social studies. They gather, organize, and summarize single items of information. Through this process they transform single items of information into concepts and generalizations that are more usable than the isolated pieces themselves (Dworetzky, 1990; Fabricius & Wellman, 1983).

Fourth, recognizing patterns in their lives helps people make decisions based on information. It also helps them process information. The ability to recognize patterns and process information helps solve the problems that confront citizens. Solving problems requires an individual to wait to reach a conclusion until there is enough information available to choose the best solution.

Finally, social studies involves students in the development and analysis of their own values, and the application of these values in social action (Sunal, 1990, pp. 3-4). When students solve problems and make decisions, they are analyzing and developing values—those things that one believes to be important in life. Values shape people's responses to their social world and often lead to social action. Social action can be on a small scale, such as writing a letter to a Senator, or on a more time-consuming scale, such as working in a recycling center. Social studies is put to work when a value decision is made and social action is taken.

In social studies, students learn a variety of ideas and skills. The ideas can be concepts or generalizations. They can also be effects, representing values and attitudes. Students also learn a wide range of process skills, which include skills in data gathering, such as observing and interviewing; in data organizing, such as classifying and interpreting observations; in data processing, such as finding patterns and hypothesizing; in communicating, such as reporting and informal discussing; and overall thinking skills including critical thinking, reflective thinking and decision making (Sunal & Haas, 1993).

Process skills cannot be taught independently of content; however, some lessons may focus on the process skill rather than on the content. The content is used as a vehicle for teaching the skill. For example, students learning the skill of interviewing need to plan, conduct and evaluate an interview about a specific topic. Students learning to make observations need to identify as many characteristics as possible about a specific set of materials.

Concept teaching is a critical component of social studies. Once students learn a set of concepts, it is important to encourage them as they attempt to identify the relationships between concepts. When they have established a relationship and verified it through evidence, they have created a generalization. Generalizations are more abstract and more difficult to understand because of the several steps that are involved in forming them. To reiterate: the learner must first understand the component concepts; second, the learner must hypothesize a relationship between those components; and third, the learner must gather evidence to determine whether the hypothesized relationship can be supported.

Social studies also considers values and attitudes, which are complex and require thorough and appropriate teaching. Teachers should focus on reasoned consideration of values and attitudes, not on indoctrination. Important questions considered by educators include: Are there values and attitudes that are fundamental to life in a democratic society? If such values and attitudes exist, what are they? If they can be identified and agreed upon, what strategies best teach them to students in a manner that avoids indoctrination and preserves the democratic approach fundamental to a democratic society?

All of these—concepts, generalizations, process skills, values, and attitudes—are components of social studies and can be effectively addressed using learning cycles. The learning cycle model is presented later in this chapter, just prior to the sample activity. The process can incorporate any strategy from learning stations to direct instruction, particularly during the invention phase.

PERSPECTIVES ON TECHNOLOGY AND TECHNOLOGY EDUCATION

Technology is an inherent part of both the physical and social worlds. Linking them together creates a higher order of understanding because children live in both worlds. Children often meet the social realities of the physical world through technology. For instance, many children form their first attachments to stuffed animals that emit lifelike sounds, and soon they are playing a video game where they rescue someone in distress. Technology also confronts them when they face the physical realities of the social world, when a toy fails to operate or when the lights and the telephone are cut by a storm. Technology allows students sense with wonder, concern, excitement and fear the social realities of the physical world. They are eager to look, poke, touch, taste, and smell. Through their senses children acquire concrete understandings of technology. They will use these understandings in social settings and formal learning later in life as they continue to define and develop meaningful concepts.

Technology is defined here as the means people use to transfer, transform, transmit, or transport resources. Technology is frequently a component of the social action individuals take. It can be either a contributing stimulus to that action or a vehicle through which social action is accomplished.

As a catalyst, technology might be a goal or an end product sought, or it might be used to bring about another end product. For example, students might be involved in activities designed to generate money with which to purchase a computer for their classroom or they might lobby their board of education to set aside money for the purchase of computers. In another setting, students might generate a report through the study of the attraction violent computer games have for children. They might survey their peers and family members to determine the level of widespread use of violent games among their school's population and to identify concerns children and adults have with such games. Subsequent social actions could include a boycott of stores selling this software, writing letters to their congressional representative or becoming involved in a discussion group focusing on why they enjoy such games and how they can wean themselves from them.

Technology can also be used as a vehicle for social action. Using the same example cited in the previous paragraph, students might produce a video program and make it available to other schools. The video could discuss the pros and cons of censoring violent computer games. The video might stimulate discussion among children about these games and of censorship issues. Or they might use a word processor to create a newspaper that includes child-authored reviews of software games. In this instance the technology is a vehicle for social action. In many cases such as the above, computer technology might be both an instigator and a vehicle for social action. The above examples have focused on using particular types of technology, but social action also extends to processes such as designing technology.

Technology education has been defined as an educational program that assists people in the development of an understanding and competence in designing, producing, and using technology products and systems and in assessing the appropriateness of technological actions (Wright & Lauda, 1993). Technology education can foster children's involvement in social action. Because technology can serve as both an instigator and a vehicle for social action, elementary school technology education (ESTE) programs can develop in students an awareness of the role of technology. Students must be educated to recognize both the potential of technology for social action and its explicit role in social action, which can be readily accomplished in the social studies discipline.

The breadth of possibilities for integrating technology with social studies is staggering. Students need to study the history of technology to understand how technology has always been a part of human society and has significantly defined the characteristics of human societies. They need to study the early role of technology in people's adaptation to their environment and in their evolution into modern social beings. Students must understand technology's role in our cultural geography and in our adaptation to physical geography. The interactions of our political life and technology represent another important area of study. Students need to study the two-way effects of technology on individuals and groups—the depletion of natural resources and the creation of problems of wastes disposal, and its use to help people deal with some of the scarcities of metals, food and other goods and services imposed by nature. Students need to understand the role that technology plays in exacerbating our needs and wants. All of these possibilities are examples of how humans must go about the task of understanding and assessing technology's impact on society in areas considered through social studies.

TECHNOLOGY AND SOCIETY: A GREAT CONNECTION

Technology and society form a great connection. One seldom exists without the other. ESTE draws on this connection by being interdisciplinary and involving social studies. It is also important because it helps students build relationships between traditional subject areas. This kind of teaching brings social studies closer to life outside the school—learning that is not compartmentalized into content areas. The classroom and the world become one integrated experience.

Integrating the perspective of both social studies and ESTE can be achieved through interdisciplinary units. Current literature and research support curriculum integration and have shown significant benefits from its implementation (Lounsbury, 1984, Mancino, 1993). For decades, there have been concerns expressed regarding curricula designed solely around separate subjects (Mancino, 1993, p. 2). However, Alberty and May (1987) report that a review of 25 years of literature indicates that the traditional approach in elementary schools is pervasive (p. 322). The pervasiveness of a traditional, highly separated subjects approach has been supported by movements focusing on measurable outcomes, high stakes testing, and accountability according to Mancino (1993, p. 40), and has resulted in fragmented curriculum that lacks creativity and diversity. Recent education movements have focused on the areas most tested, such as reading, and diminished the import of those areas given less time on the tests, typically social studies and science (Mancino, 1993). Usually technology education also has no role at all in standardized tests. Teachers generally are not able to make connections between broad outcomes and the disciplines they teach, due to their own socialization and education (Kraft & Black, 1993). Integrating social studies with ESTE activities enables teachers to make connections, to bridge understandings, and to make practical applications of all the social studies.

AN INTERDISCIPLINARY UNIT

An interdisciplinary unit begins with brainstorming. Using a sheet of butcher paper and a marker, teachers write down ideas, possible skills, and activities as they are generated. This process usually works well when a web is developed. Any number of teachers may be involved. No evaluation of any item occurs during the brainstorming.

When the initial brainstorming is completed, the suggestions are reorganized into a working web. At this point, when a group of teachers is involved, one teacher should take the leadership position to coordinate activities related to the unit. Since coordination is a lot of work, the position should shift when another unit is planned, developed and implemented. The most appropriate ideas, skills, and/or activities are chosen for the interdisciplinary unit's working web. The leader develops a culminating event or activity involving the range of ideas and skills represented in the unit to serve as the final integration of the unit. Finally, a timetable is developed that indicates when various ideas and/or skills will be taught.

Implementing the Interdisciplinary Unit

Interdisciplinary technology/social studies units can be implemented over any period of time ranging from a few days to much of the school year. The topic should determine the unit's length. Since there are endless possibilities for social studies-technology integration, teachers should design and implement specific units relating to this integration. In addition, social studies-technology integration should be an underlying theme throughout the year in all units, no matter what their topic.

Communication is vital when more than one teacher is involved in the implementation of an interdisciplinary unit. In shorter units, teachers meet daily to review what has been accomplished and what will be addressed on the next day. In longer units, teachers meet twice a week to review and plan ahead. The lead teacher for the unit works with the general outline or web that has been developed for the unit and coordinates activities leading up to the unit's culminating activity. The coordination of materials other than those usually available in the classrooms is also the responsibility of the lead teacher for the unit. As the unit is taught, the lead teacher determines where overlap is occurring and what areas have not been addressed. These are discussed during group meetings and alterations are made in the schedule or in the activities planned.

Teachers have learned to expect interruptions such as a fire drill or an outbreak of the flu causing widespread absences. A wide enough time frame for the interdisciplinary unit will enable teachers to accommodate the curriculum to such interruptions.

Evaluating the Interdisciplinary Unit

Assessment should serve two broad purposes: first, to answer questions and provide feedback with regard to student learning and second, to provide data with respect to the effectiveness of the lesson and unit plans. The most common or traditional approach to this step is to prepare a post-evaluation instrument (a quiz or test) that would be administered when the students complete the unit. The instrument can be used to provide feedback on student learning and provide additional feedback from the students about the effectiveness of the unit.

Because an interdisciplinary unit is a relatively nontraditional form of instruction, other types of assessment should be strongly considered. Among these might be a student writing project, artwork, a map, an interview, or a group/individual project. Assessment can also include other items and approaches. Informal and semiformal methods, as well as having students develop portfolios of their work, can be incorporated into an assessment plan. The assessment instruments should be designed to evaluate each type of learning outcome that is included in the unit. Measures should be developed to evaluate generalizations, concepts, process skills, and effects. Students should also be asked for feedback on how they reacted to the unit. Possible questions include: How satisfied are you as a learner? What could the teacher have done to make you more satisfied? What were your favorite activities? Why? What were your least favorite activities? Why?

As part of the evaluation of the unit, the KWL procedure can be utilized. This is a three-step procedure utilizing the following focusing questions:

1) What do you ***Know*** about _________?

2) What ***Would*** you like to learn about this topic? and

3) What did you ***Learn*** about this topic?

Prior to beginning the writing of lesson plans the teacher involves students in a class discussion of "What do you *know* about _________?" in relation to the unit's topic. Their comments are recorded on a chart for further use in the "L" portion of the procedure. Then the discussion continues around the second question, "What *would* you like to learn about this topic?" Note that students do not always know what they would like to learn about a topic because they may have little experience with an area. Students' comments are again recorded on the chart. After completing the unit, the class discusses the third question, What did you *learn* about this topic? Their comments are added to the chart begun earlier in the K portion of the procedure. Curriculum development and instructional planning are part of a large cycle. One of the most important parts of the cycle is a period of time devoted to gathering feedback on the unit, and reflecting on the effectiveness of the unit. This is particularly important when dealing with the complexities of an interdisciplinary unit. Here are some questions to consider when reflecting on the unit:

- what evidence of motivation to learn about the topic did you find?
- what evidence of learning about the topic did you see?
- to what extent did students attain the learning objectives?
- did the lessons flow together well?

- what did the students remember and not remember from day to day?
- which lesson was the best? Why? Would you have predicted this?
- would you use this unit again in its present form? If not, how would you change it? What modifications would you make?

IDENTIFYING POTENTIAL UNIT TOPICS/ ACTIVITIES FOR THE TECHNOLOGY-SOCIAL STUDIES UNIT

The most meaningful topics are those that are concrete enough to be thoroughly investigated. Depth, not breadth, appears to result in the most meaningful learning. As much or more content can be covered by going deeply into a narrow topic rather than by broad coverage of a wider topic. Topics that are emotionally charged also result in more meaningful learning. Students are more likely to understand the issue(s) related to the topic as being of real concern. The topic should be one that allows students to develop an informed opinion about a complex problem. It should be narrow enough for students to grasp its important details but complex enough to lack obvious solutions. The topic should have ethical and technical dilemmas so that its need for action includes an emotional urgency. If possible, local issues, where there is access to primary source materials and people, are best. Finally, the topic should have potential for the creation of a final product by students that shares knowledge and kindles interest. An abstract topic with little concrete material related to it may generate a limited research paper but does not generate an easily shared final product (Huhtala, 1994). The following sections discuss the content topics of social studies and how these topics can be integrated with technology.

Technology and Geography Education

Geography educators categorize geographic concepts under five themes: location, place, relationships within places, movement and regions. The themes are used at all grade levels because they can be understood at different levels of concreteness and abstraction. Geographers recommend that the youngest students examine the environments they know and can explore through their own observation and interactions. As students acquire more skills, they use more indirect sources of data. This method will expand their knowledge about the world and their definition of each theme to include new examples and new relations or generalizations about the themes (Sunal & Haas, 1993).

Location Location is a fundamental theme and assumption of geography. There are absolute or exact locations such as the room in which the school kindergarten is located. There are also more general or relative locations, for example: "Most Buddhist temples are found in southern Asia" or "Louisiana is south of Missouri."

Some of the activities that fall into the location theme involve learning to locate places in the community, on the earth, and on a map or a globe. Technology is important in determining location. People use simple technology, such as a compass, and complex technology, such as the Land Sat satellite, to determine location. Once determined, location is displayed on globes, wall maps and computer-generated maps. All of these represent products that people have designed and use.

The process of determining location and making decisions regarding how to convey information about location is one that integrates technology and social studies. This process can be used in an ESTE activity where students plan a route for a local field trip. During the planning process, students should consider the following questions: What means of transportation will they use? Will the interstate be full of heavy traffic at the times they plan to be traveling on it? If it is winter and they are living in the northern USA, can they expect delays caused by slower speeds over ice-covered bridges and similar problems? How far away will they have to park once they get there?

Place Place describes both the natural and human (cultural) features of the landscape. To address the theme of place, activities should involve concepts that describe different features, such as mountains, plains, capital cities and the developing world. Students should gather data and answer questions to help them describe places. Such questions might include: What is the lay of the land? How much water is present at this place? Are there many people in this place? Have the people done much to change the appearance of the area? (Sunal & Haas, 1993).

Activities that address the place theme integrate technology into most considerations. One activity might involve the students planning a trip to a place. They will need to decide how they would get there and how they would move about once there. They could consider how technology influences the culture of that place by answering the following questions: How many people have television sets? What are their favorite programs? Do they see a lot of news from the news channels? Students might also compare charts or pictures for similarities and differences.

They will be able to make decisions regarding the type and level of technology commonly used in that place. For example, a group of fifth-graders recently watched a video about Mexico. They were particularly impressed by the amount of cars on the road—they had thought Mexicans mostly traveled by burro. Other place activities that involve technology are making or reading climate graphs and identifying nations from clues.

When studying place, students can construct maps that display characteristics of the place, such as rolling hills and lakes on a state map. Or students might use a computer program to generate diagrams of buildings that can be folded into three-dimensional models to be used in a map of a single block on a street. Students might also make dioramas or use the program LOGO to draw a computer-generated map that displays the characteristics of a place.

Relationships Within Places: Humans and the Environment

The natural environment tends to limit what people can do in a place. However, human cultures demonstrate the many ways people have invented to deal with these limitations. The theme of relationships within places—humans and the environment—addresses this effort. Technology has always been part of people's efforts to deal with the limitations resulting from the natural environment. In dry areas, where there was not enough water to grow food, people found ways to bring water to where it was needed. Today people in some dry areas supplement local production by using advanced transportation systems to import food.

The topics for student discussions falling under this theme are many. Students might discuss the causes and solutions to problems of endangered species. They might determine ways the weather has influenced how their use of technology and its use by people in another location. They might compare graphs of population density and elevation and consider how technology enables people to live in greater densities at different elevations. They might read about earthquakes, tornadoes, floods and other natural phenomena and discuss how people try to forecast these natural occurrences and counteract their potential for destruction.

Another way to integrate technology into this theme is by having students examine topographic maps available from the U.S. Geological Survey to identify housing patterns. This government department provides services on the Internet. Information can be obtained at their web site (http://info.er.usgs.gov), from a visit to actual sites, or by viewing photographs of sites. This information can be used to identify reasons for the housing patterns. One pattern example is that people in hilly areas often build houses on the flattest land available– the floodplains near rivers. However, this construction pattern can expose them to flooding. Students can explore the effects of building on a floodplain by reading reports of floods that have occurred, building a clay model of a valley then pouring in different amounts of water to note different flood levels. The students can then build obstructions, such as levees along the river's sides, and note how these obstructions constrict and raise the level of the water in the riverbed and eventually overflow with great force.

Movement People do not stay in one place nor do they only use resources from the place where they live. The movement theme addresses both of these characteristics. With an ever-increasing use of technology, the interactions of people will probably continue to increase. The movement of ideas and products affects not only places of origin and destination but also places along the way.

These places are affected when raw materials are extracted, new products are grown or produced in factories and transportation centers are expanded or established. Another affecting factor is through new ideas, such as preservation, conservation, and democracy being heard and attempted in new places. There are also systematic movements among the natural forces of the earth. For example, currents carry warm and cold water to new locations; they also carry pollution created by people to new locations throughout the globe (Sunal & Haas, 1993).

Students can explore these themes in ESTE activities that have them locate cities or nations where their families have lived and locate where their food is grown. Students can trace the path of a product from its origins to them by constructing maps and models that map the path of a food from the farm on which it is grown to the home in which it is eaten. The first step in the process is to contact a local farmer who sells vegetables to supermarkets. During a visit to the farm, the whole class or a small group can conduct an interview with the farmer focusing on where the products are sold. Next, they can visit the supermarket that sells the product and interview people purchasing it. Finally, they can locate the addresses of some of the individuals who purchased the food. All of this data can be used to create the map or model describing the farm-to-home route taken by the food product. Another activity might have students regularly keep track of the places they hear about on the news.

Regions It is difficult to conceive of the scale of the world, so geographers frequently divide it into regions to conduct their studies. After studying many regions, geographers begin to get a picture of how the entire world works as they investigate the interactions of regions. A region can be as small as a single classroom or as large as North America.

Students can study how regions form and change in ESTE activities, such as listing the differences in parts of their city, identifying boundaries for states and nations, dividing their school into areas where certain activities happen, and conducting an extended study of Latin America or the Old West. Technology has a central role in each of these activities. For example, when children divide their school into areas they will often decide that the cafeteria is determined by the types of equipment present: individual trays and utensils, a large refrigerator, and large serving trays. They might also identify the region known as the cafeteria by the processes occurring there such as the "assembly line" used by the personnel to serve meals to students.

Tools for measurement and the demarcation of boundaries can be introduced to students as they study regions. Young students should use lengths of string to measure off and demarcate regions. They can use one student's foot as the measure. Eventually students can use standardized measures such as a meter.

Older students might carefully map regions of their community. This can be accomplished using several methods. A walking survey of a region is important. Aerial pictures, if available, provide quite a different perspective from the walking survey. A drive or a ride on a bus provides another perspective. After several approaches have been used, the whole class can discuss the data they have acquired. Following extensive discussion of the data, a final determination of regions within the community can be made. The students will have to carefully identify the criteria by which a region will be identified. A criterion can be the "lay of the land," or it might involve the presence or absence of industry, homes and parks. These are difficult decisions that take time and careful discussion. The criteria can then be used to map out the regions of the community.

Technology and History Education

Everyone needs to know about their past. The major questions that face history educators are: How do we learn about that past? And how can that past be made meaningful to us as individuals and as citizens of an increasingly interdependent world? Historians generally agree on history as having three important aspects, which are identified in the following definition: "History is a chronological study that interprets and gives meaning to events and applies systematic methods to discover the truth" (Sunal & Haas, 1993, p. 278). The historian has limited information with which to work. There is only what has been preserved from the past to provide hints as to what may have taken place. Clues, not complete records, are usually available. Clues reflect the perspectives and memories of their preservers. The historian interprets the evidence, deciding on the degree of its importance and its accuracy. The ability to place times and events in chronological order is important in establishing cause-and-effect relationships. However, chronologies are often guesswork and so should not be the goal of history education.

Technology plays an important role in helping historians find clues and organize them into patterns. An Anasazi drawing on a wall in Chaco Canyon, New Mexico, a cuneiform clay tablet from Iraq, a hand-written medieval bible from Sienna, Italy, a mass-produced McGuffey's reader from 1867, a copy of the Philadelphia Inquirer from 1933, a set of messages on a computer bulletin board from 1992, and a fax from 1994—these are all examples of technology that provide historians with visual clues that can be processed to unravel history and seek to establish cause-and-effect relationships. Historians may also find clues in the technological product itself: a carriage preserved in a bog on the Russian steppe in 1200 BC, an Apple IIe computer from an Ohio elementary school, or a hand-crafted straw sandal from a Native American town in present–day Georgia dating from the 1600s. Technology cannot be separated from humans, and the history of technology is the history of the human-made world.

Students need to become aware of the use of technology in finding and analyzing clues:

- The use of computer databases to sort out clues.
- The use of tiny video cameras to investigate the inside of a tomb without disturbing its contents.
- The duplication of the process for making ancient stone tools to discover how primitive people lived.

These are only three examples of how historians use technology. Students also need to study the history of technology—for example, how people have moved from using bowl boats and canoes for transporting goods to using supertankers. They can also begin to study how technology has impacted people over time. It helped people create cities, but cities also created an easy avenue for the spread of disease among many people crowded into a small area. Eventually, technology helped people overcome many diseases. Students need to study the interactions that have occurred in our history in order to appreciate the pervasive role technology has always had in human society.

Using tools and processes to make items as our predecessors made them is one way to involve students in a hands-on exploration of the past. Students can, for example, collect parts of plants such as onion skin, carrot skin, blueberries, and dogwood bark. They can boil these to derive natural dyes to achieve many different fabric colors. By adding a mordant, such as alum, to the yarn or fabric, they can set the color. They can weave pieces of yarn into a mat. This is a process many people had experience with during the nineteenth century. The replicating process is rarely completely accurate because the same exact process will not be duplicated. For example, the students will probably not boil their dye over a wood fire nor grind their own alum nor make the yarn. Nonetheless, each step in the dying and weaving process can provide a contrast between older and modern technologies. Teachers can incorporate many activities into the curriculum to provide opportunities for the consideration of the role of technology. Some activity examples include: paper making, cutting and gluing hand-made envelopes for Valentine's Day cards, making a corncob doll, stitching together and stuffing a leather ball, making a crystal radio set, and quilting.

Traditional children's toys are a fine beginning point for lots of interesting studies of history and technology. These toys are generally made of locally found materials that were cheap in the past. Often they are wooden or made of byproducts for the food gathering and making process. These byproducts include the corncobs, dried apples and nuts used in doll making. They also included the pig's bladder which was cleaned and then blown up to make a ball. Most toys were sturdy and not easily broken. When a part of a toy did break, it was easily replaced because it was not finely machined nor expensive.

Because of the natural interest children have in the past and because past technologies were simpler than today's technologies, there is often a tendency to overrepresent historical technological processes in the classroom. The argument often made by critics of the sometimes simple products of elementary school children as they study history does not take into account, however, the role technology activities play in understanding our present culture. Humans engage in complex social activities. As children begin to understand their modern technological and economic world, they often learn complex concepts through a connection with simpler concrete objects.

Technology and Economics Education

Economics is part of our everyday lives. Most of us can't remember the first time we heard that we could not have something because there was not enough money or time for it. We continue to want more than the resources available to us can provide. This generalization is the basis of economics. The solutions that people use to get around this generalization are the content of economics. Social studies educators strive to help students learn the importance of making rational decisions about the use of scarce resources.

The National Council on Economic Education (formerly the Joint Council on Economic Education) developed the *Master Curriculum Guide in Economics*: A Framework for Teaching the Basic Concepts (Saunders, Back, Calderwood, & Hansen, 1984). The framework divides basic economic concepts into five areas: fundamental concepts, microeconomic concepts, macroeconomic concepts, international economic concepts, and measurement concepts and methods.

Fundamental economic concepts include: scarcity, opportunity cost and tradeoffs, productivity, economic systems, economic institutions and incentives, and exchange, money and interdependence. Microeconomics is the study of individual households, companies and markets and how resources and prices combine to distribute wealth and products. These concepts include: markets and prices, supply and demand, competition and market structure, income distribution, market failures and the role of government. Macroeconomics is the study of the economy as a whole. Its major concepts include: gross national product, aggregate supply, aggregate demand, unemployment, inflation and deflation, monetary policy, and fiscal policy. International economic concepts include: absolute and comparative advantage and barriers to trade, balance of payments and exchange rates, and international aspects of growth and stability. Measurement concepts and methods include: tables, charts and graphs, ratios and percentages, percentage changes, index numbers, real versus nominal values, and averages and distributions around the average.

Technology is important throughout these concepts as both the basis of information on which the concept is built and/or as the means of deriving information related to the concept. An activity that integrates economics and technology is making and selling a product. This activity can be as simple as assembling such items as bandages, single-use packets of antiseptics and cotton swabs into a first aid kit or as complex as writing, editing, assembling and producing a booklet of maps and descriptions of state parks and recreation areas. Any activity that includes market surveys, financing the cost of materials and calculating the selling price of the product, and keeping records of expenditures and profits, engages students in economic activities. Among related activities are computing the best buys for similar products, having parents visiting class and talking about what they do at work, and visiting a fast-food restaurant and observing the production process. Other economic activities that involve technology include performing a cost-benefit analysis to determine the best short-term and long-term uses for the tropical rain forests, examining safety features on automobiles, and conducting surveys of students' homes to determine where and how they might save on the cost of electricity.

One approach used to teach economics is the mini-society and kinder-economy (Kourilsky, 1977). The kinder-economy program is specifically directed at kindergartners. Both approaches involve children in classroom experiences designed by the teacher. The teacher involves children in experiences related to a specific concept. A problem is set up in the children's classroom society, and they decide how to solve it. Next the teacher debriefs the children focusing on the concept experienced. Finally, the teacher involves the children in further experiences that expand on the concept. For example, the teacher might arrange an initial scarcity situation in the classroom, such as not enough chairs to provide one for each student.

Alternative solutions are generated, their consequences predicted, and a best solution agreed upon and implemented. In many such programs, students operate businesses, make products, police themselves, inventory equipment, and maintain the classroom.

Technology is woven throughout the program. Problems such as scarcity may be solved or exacerbated by technology. Daily tasks such as maintaining the classroom are technology-dependent. Production processes involve technology. Decisions regarding resources needed involve technology. The classroom society reflects the larger human society in its complete integration of technology.

Whether or not a mini-society program is used, economics education offers many opportunities to consider technology. Students can be asked to create a hamburger "with everything on it" from different colors of clay. After they have worked on their own to make the bun, the hamburger, the pickles, lettuce, and a glob of ketchup, and to assemble all the parts, the teacher can introduce an assembly line. Using the assembly line, they will find hamburger manufacturing to be faster, but perhaps also boring after a time. The positive and negative aspects of technology can then be discussed.

Students can also construct a model of a zoo as an end product of part of their economics studies. Two units are available from the National Council on Economic Education (formerly the Joint Council on Economic Education) in which students construct a zoo, Zooconomy 1 and Zooconomy 2. In these units students have a set amount of money and space with which to work. They have to decide which exhibits they will have and must consider how to balance off a costly exhibit, such as a penguin house, with less costly exhibits, such as a petting zoo. The students investigate the costs in air conditioning and other technical features of a successful penguin exhibit. If they decide that they want the exhibit, they balance it with cheaper exhibits and with moneymaking enterprises. They may choose to give up exhibit space to a moneymaking train ride or to a popcorn stand. They will need to find out what sort of trains are available, what they cost, why the costs vary, which are most cost-efficient to maintain, and how long it will take for the train ride to pay back their initial investment. Eventually the students achieve a consensus on what exhibits, commercial enterprises, and other facilities the zoo will have based on the money and space available. Then, they construct a large scale model of their zoo.

Technology and Political Science, Civics, and Law Education

At the elementary level, citizenship in a democratic society is the focus of political science, civics and law education. This area of social studies education focuses on three types of questions: Who has the right and power to govern? How do governments organize themselves to make and enforce political decisions? How do groups of people influence the political process? Citizens in a democratic society have special powers and obligations including: bestowing both the power and right to rule on a government of their choice; selecting those who perform the day-to-day governance; debating and compromising to instruct the government on the needs of the people and the types of policies desired; monitoring the actions of governments and keeping informed on issues related to the collective good; and balancing their own self-interest with the collective good (Sunal & Haas, 1993).

The capacity to participate effectively in a free society requires knowledge of the political system and a clear understanding of what one is trying to accomplish. This goal is best served if citizens have: (a) an interest in public affairs and a sense of "public regardedness," (b) tolerance and respect for conflicts arising from divergent values and beliefs, (c) the ability to examine consequences and to assess the likelihood of alternatives achieving desired goals, and (d) the ability to assess both long- and short-term consequences (Brady, 1989).

In today's societies many decisions citizens make involve technology. The voting process itself involves the use of technology whether one votes using a pencil and paper or a voting machine. Proposals for widespread electronic voting present citizens with a new issue to weigh and consider. Citizens who file their income tax forms via computer are using technology. When citizens obey traffic signals, they respond to stimuli from the traffic signal and from other vehicles. Television and radio enable citizens to listen to and evaluate the debates of political candidates and a president's state of the union address. Citizens can participate in call-in shows on radio and television, send electronic mail to elected officials or visit their home page on the Internet, or even talk to candidates directly and judge their responses afterwards. The civic action process itself heavily incorporates technology.

The decisions citizens make often involve technology as a factor. Modern societies deal with questions raised by the growing technological ability to carry out genetic manipulation in human beings. As another example, new large-scale Doppler radar systems are enabling weather forecasters to produce more accurate forecasts. These systems also mean that citizens have more information about floodplains and other natural features. The additional information results in new questions concerning whether homes and businesses should be built in floodplains and whether levees should be built to protect them. Another example is presented by the fact that databases are widespread and citizens increasingly find themselves receiving mail from advertisers who have bought their name and information from various sources. Citizens will eventually have to decide how much information should be easily accessible and sold. Technology raises many questions that citizens must decide, such as: Is a new water treatment system needed? Will this new technology create new jobs? Are government funds best spent on testing a new technology or on some other endeavor?

The technology-related decisions facing citizens are many, and both the scope and number of those decisions appears to be continually growing. Students should begin examining issues from both the role of technology in the decision-making process and the questions raised by technology about which citizens must make decisions. Some activities that incorporate technology and citizenship education include: students graphing the number of elephants in the world over the last 100 years and investigating reasons for their decline and means to try to stop the decline; reading about people who made trips around the world and incorporating these trips into a database and finding information, such as that the time to accomplish the trip has decreased steadily as technology increased; reading about refugee problems and how technology both contributes to them and relieves them; examining the tradeoffs involved in the quality of information and the speed of presenting a news story about a major issue or event; using a satellite downlink during a period of unsettled weather conditions to examine current weather and decide if warnings should be issued in the school to watch for possible thunderstorms, snowfall, icy conditions, or tornado-like weather; and taking part in a disaster relief drive and determining how technology can respond to people's needs.

Technology and Psychology, Sociology, and Values Education

Psychology education works toward the goal of understanding and accepting our individuality. Sociology education focuses on helping people understand their social nature and the social groups they form. The development of the attitudes and values integral to each person's personality supports the goals of individual and social development. Psychology and sociology education and the development of attitudes and values are controversial areas in a democratic society that encourages a variety of opinions and the public discussion of those opinions.

As students learn to establish positive and productive relationships with others, they frequently utilize technology, particularly in personal communication. An electronic bulletin board or a handwritten note both involve communication. The telephone is a major communications device in the USA among students. Groups cannot be effective and cannot long survive without productive communication. Students need to understand, be comfortable with, and productively utilize technology. Thus, technology education is an important component of individual development.

All individuals have attitudes toward technology and place some level of value on it. Attitudes and values are influenced by knowledge. As teachers integrate technology education with social studies education, students can become more knowledgeable about these attitudes and values. Technology can then be better understood and appropriately used. If technology education is integrated with social studies education, it will have positive effects on individual awareness and self-esteem and on the individual's role in groups.

There are many technology activities that can enhance a student's understanding of self and interactions with others. Students might use a time line program to plan their day. They can use a word processing program to keep a reflective journal. They can set up meetings of groups through electronic mail. Students can also make model airplanes, knit, build a radio from a kit, sew a costume for a play, build a bird feeder, use a pedometer to determine how far they have walked, or use a complex exercise machine. Each of these activities enables a student to develop higher skill levels in a specific area. The development of personal skills contributes to feelings of personal accomplishment and self–confidence. Students who have confidence in their personal accomplishments are often better able to contribute to group discussions and decision making.

Construction activities, including those connected with student hobbies, are a good vehicle for the development of personal skills and confidence. Sometimes students will benefit from working with a partner on a project in which one student lacks a needed skill and/or experience. The dyads should be changed with different projects in order to insure that all students have opportunities to take a leadership role. These experiences build confidence in group situations as students work through the problem solving and decision making involved in a construction task.

The discussion above has separated some of the disciplines that contribute to social studies education. In the social studies program, these are typically integrated creating an interdisciplinary program. Hence the discussion above should provide background information that indicates some of the many possibilities for integrating technology education with social studies. It should not suggest that social studies be broken down into discipline-dominated units when ESTE is integrated with it.

Social studies integrated with technology activities provides students with meaningful learning. A short discussion of "the learning cycle," a method of organizing for instruction, is presented below and is used in the development of the sample activity unit following this chapter.

TEACHING FOR MEANINGFUL LEARNING: THE LEARNING CYCLE

As students examine people-technology relationships, it is important that teachers strive for meaningful learning. Teachers should help students generate personal knowledge and form accurate ideas based on their own investigations of materials and events (Sunal & Haas, 1993, p. 20). The learning cycle is an effective approach used by many teachers to help students restructure their personal ideas so that their misconceptions and alternative conceptions are reduced (Karplus, 1979; Osborne & Freyberg, 1985). A learning cycle contains three main lesson phases. The lesson begins with the exploration of an idea or a process skill. The exploration leads to a more teacher-guided invention of the idea or process skill. Once students have invented for themselves the idea or process skill, the lesson moves on to an expansion of that idea or skill through additional practice and trials with new data or in new settings. The teacher provides materials and sets up events and situations that are appropriate to students' level of development. With the teacher's guidance, students compare their ideas and skills with those of the teacher, textbook, guest speaker, or literature. During this process, the teacher monitors students' progress and gives feedback as necessary so that the students form relevant, meaningful concepts.

There are five essential prèrequisites for meaningful learning to occur. First, the change in reasoning should not be too great (Karplus, 1979). Second, what is taught must be related to the prior knowledge of the students (Seiger-Ehrenberg, 1991). Third, many concrete examples must be used in situations requiring active mental and physical involvement by students (Piaget, 1969). Fourth, practice must be provided (Costa, 1991). Fifth, students must be given time to reflect, make mistakes, revise, and form new ideas or skills (Barell, 1991).

Teachers using the learning cycle must adapt their instruction to enable students to construct their own new knowledge. When constructing their own knowledge, students restructure existing knowledge, connect new knowledge to what they already know, and apply the new knowledge in ways that are different from the situation in which they first learned it. At the beginning of a lesson the teacher selects an open-ended activity that will diagnose what the students currently know–their prior learning. Then they focus students' attention on the idea or skill that is the goal of the lesson and help them relate their prior learning to new learning (Seiger-Ehrenberg, 1991). Finally, teachers involve students in an exploration activity that challenges them and brings them to a realization that their current idea or skill level is not adequate to the problem at hand (Sunal & Haas, 1993).

During the second part of the lesson, the invention, the teacher involves the students in activities that provide explanation and examples. These activities may involve reading a textbook, working with a discussion group, carrying out an experiment, watching a video, or accessing a CD-ROM or the Internet for information. During the invention, the teacher explicitly addresses the key idea or skill of the lesson. The teacher achieves closure with an explicit statement or definition of the idea or skill being taught. The teacher guides students in a reconstruction of their existing ideas so that they more accurately and appropriately represent the knowledge in the field. The central role of the teacher in this part of the learning cycle is that of a guide.

In the expansion, students practice working with the new idea or skill they have just invented in different situations. As they use the idea or skill, they extend its range of applicability.

SUMMARY

Technology impacts people in all societies. Teachers have a pivotal role in helping students understand the relationships between people, their societies and technology. Social studies derives its goals from the nature of citizenship in a democratic society and from one society's links to other societies. It draws its content from the social sciences and from the personal and social experiences of students and from their cultural heritage.

Technology is an inherent part of the physical and the social world. It links them together and creates a higher order of understanding. Children live in both worlds. They often meet the social realities of the physical world through technology. Technology activities in the elementary school classroom are closely intertwined with social living and social action. Social studies education, involving many separate fields, is typically integrated, creating an interdisciplinary program. An integrated technology activity can present social studies in ways that are most meaningful to children. Social studies should not be broken down into discipline-dominated units, especially when technology education is integrated with it.

Integrating ESTE and social studies into an interdisciplinary unit is an exciting and a challenging experience. It requires a teacher to step beyond traditional disciplinary confines. Such a step places teacher and students into a world without the usual boundaries. Because those boundaries have changed, it will be a world with challenges and one that is less predictable. The challenges and lowered predictability make the interdisciplinary classroom more like the real world. Students who have opportunities to work with interdisciplinary ESTE-social studies units are participating more fully in the world. They are learning skills and knowledge that will enable them to better function in the classroom and in the world beyond the classroom.

An Interdisciplinary Technology - Social Studies Unit

LESSON ON THE DESIGN PROCESS

Prerequisite concepts:

Social studies concepts: processes for group decision making, awareness of technology waste production, the need for conservation of resources.

Technology education concepts: energy of motion, potential energy, mechanical energy, chemical energy, electrical energy, products, production.

Exploration:

Objective:

Students will design an item they can use in school from one or two school milk cartons and other throw-away material.

Materials:

- two milk cartons per student group (see options, in Procedure);
- paper scraps;
- classroom sets of scissors, marking pens, glue; rulers; staplers;
- assorted items, such as buttons, wire, paper clips, and string.

Procedure:

1. Ask students to use a common packaging item that is normally thrown away such as a school milk carton (other options include plastic milk jugs, soup cans, toilet paper rolls) to invent another item that would be appropriate for use in the classroom. As they ponder their task, ask them to consider the question: How can this waste be made into something useful? Have students work in triads to foster brainstorming and discussion. Their product must require them to perform some

sort of action on the milk carton that involves more than just opening it (this could create a pitcher). For example, they might cut off the top and use the bottom as a pencil box.

2. After they have completed the task, ask students to write a brief description of its use.

Evaluation:

Review the written descriptions to determine whether the item could be used in school.

Invention:

Social Studies Objective:

Students will identify the need to use multiple types of energy to produce many products commonly used today.

Materials:

Reference books

Procedure:

1. Ask students to describe and demonstrate the use(s) of their invention.
2. Ask the students to return to their groups. Have them identify one type of energy they used in making their invention. For example, they may have used the mechanical action of scissors as they cut the top off their milk carton. Have each group share the type of energy they identified and explain how it was utilized. (Do not impose any particular categories of energy on the students. This is an early lesson in the unit and should serve to create questions in their minds and avenues for further study. It should also help the teacher assess students' prior knowledge). Note how complex a discussion this becomes as many students will acknowledge their use of several types of energy.
3. Ask students to write a summary paragraph describing what types of energy their group used in making its product.

4. Close with a discussion leading to a wrap-up statement saying that several types of energy are required to make most products.

Evaluation:

Review the students' summary paragraphs to determine whether they accurately identify at least two types of energy used in making their product.

Expansion:

Social Studies Objective

Students will describe the source of the technology waste and describe the value of the production of the item versus the cost of its disposal.

Materials:

- Reference materials about container technology and the storage and transportation of food items,
- articles about conservation and recycling programs,
- materials provided in the exploration phase above, and
- other student-brought and teacher-brought scrap materials.

Procedure:

1. Ask the students to work with their group, considering two questions, Why is it necessary to package food? and What steps should a community follow to implement a plan for waste disposal of food container items?
2. Have each group write a "newspaper story" about the problem, and follow up with "letters to the editor."
3. Post the stories on a bulletin board and encourage discussion of the stories and compare the groups' solutions.
4. Have the groups define the types of waste (plastic, paper, glass, metal, etc.) and produce a unique new product using more than one type or produce a 3-dimensional model of a recycling plant or innovative landfill.

Evaluation:

Evaluate the "newspaper stories" and "letters to the editor" to determine whether students in the group described the problem accurately and give balance to the need for the product and to the problem involved in disposing or recycling of it. As students assess each other's products, have they demonstrated an ability to discuss the values of waste disposal? How well are they able to defend their creative products or 3-dimensional recycling or landfill solutions?

Technology education objective:

Students will describe the chain of energy types used to make their product, from its source to its end state.

Materials:

- Reference materials,
- computers with drawing program (if available), and
- materials provided in the exploration phase above.

Procedure:

1. Ask the students to work with their group, considering the question, What was the first type of energy we used, the second type of energy, and so on? They are to make a map showing the chain of types of energy they used. For example, in making a pencil case they may have started with human energy (chemical energy) when they picked up the milk carton; then they might have used mechanical energy (scissors), followed by motion energy, and then friction energy (as the scissors cut into the paper milk carton).
2. Have each group share its chain with the class and demonstrate the activity involved at that step of the chain. Ask the class to comment on the types of energy noted and to add in any that might have been omitted.
3. Post the chains on a bulletin board.
4. Briefly summarize the lesson by asking students to compose a statement that would describe what they have been working on. Read the statements together and use one to serve as the

summary. Write it out and place it on the bulletin board displaying the energy chains.

Evaluation:

Evaluate each energy chain to determine whether students in the group that developed it identified at least three major types of energy involved and whether these appeared in appropriate order.

Possible follow-up lessons:

Follow–up lessons could focus on one or more of the following topics: patents and patent law, the production process, assembly lines, resources and scarcity of resources, export-import regulations, child labor and protective laws, the Industrial Revolution, cost-effectiveness, decision making, product design, creative processes, energy production or energy measurement.

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Chapter 3

Mathematics, Science, and Technology

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INTRODUCTION

During an earlier era, the argument of whether industrial arts should be taught as content or method at the elementary school level had been ongoing for decades. Those who argued on the content side held that industrial arts was an essential body of knowledge that all students should learn, starting at the elementary school level. They claimed that industrial arts was every bit as essential to the education of young people as such core subjects as science, mathematics and social studies. Somehow, this body of knowledge needed to be squeezed into a curriculum that was already bursting at its seams.

Those on the industrial-arts-as-method side perhaps agreed with the notion that content was important, but they took a more pragmatic view. They recognized that there was little hope to add more content to the curriculum. Instead, they relied on the fact that the elementary school curriculum was activity based and so was industrial arts. The use of tools and the application of materials were a natural fit with the activities in which the students were engaged as a normal part of the elementary school curriculum.

Times have changed, rendering the content-versus-method issue rather moot. There were two important influences that impinged upon the issue. First, the transition from industrial arts to technology as a content base moved skill in the use of hand and machine tools to a low priority. Instead, the focus changed to the broader study of the human-made world. How humans cope with and control their world displaced a rather exclusive focus upon the production of artifacts. Technological problem solving emerged as a dominant theme.

The second influence was the myriad of reports that were critical of the status quo of education, particularly mathematics and science, that emerged in the 80s. More important were the plans for reform that resulted from the criticisms, namely, Project 2061 and its offspring; new standards for science developed through the National Science Teachers Association; and the mathematics standards that were developed by the National Council of Teachers of Mathematics. In all of these reform efforts, there are two predominant emphases: application and problem solving. And of greater significance, both recognized the content of technology as essential.

Assuming that these influences will have a major effect on education (and every indication thus far supports this notion), the content–versus–method issue is, as stated, moot. Technology will be an essential part, as content, of everyone's education starting at the elementary school level. It appears that this infusion will occur, at least at the onset, through the integration of technology content principally with science and mathematics.

Bredderman (1987), who conducted extensive research on the effects of major activity-based elementary school science curricula of the 1960s, cited evidence that elementary school students liked the idea of having technology activities in their studies. His conclusions support the notion that technology education as a curriculum thread for science is a short-term inevitability. He cautioned educators, however, that the practice seemed less defensible given all of the complexities associated with its implementation at the elementary school level.

There is a groundswell of interest among educators and others to integrate subjects in the school. At the elementary school level, integration has been the apparent *modus operandi* of instruction for decades. Integration would seem to be a natural outcome simply by virtue of the fact that in the early years of elementary school the typical class involves one teacher teaching all, or nearly all, subjects to an intact group of students. This arrangement facilitates not only students discovering relationships among disciplines, but it helps teachers to see these relationships as well (and plan instruction accordingly). Successful elementary school teachers are usually successful integrators.

Science and mathematics are relatively easy to integrate, and there are examples of success at all levels. This success is perhaps not surprising since both science and mathematics share a dependency with one another, particularly at higher levels. Science is a quest to explain natural phenomena and mathematics often provides the tools to conceptualize and communicate those phenomena.

Science has often used technology examples to illustrate the application of laws and principles. However, the activities in which the students are engaged usually intended to allow them to "discover" what is already known. Mathematics, too, relies upon technological examples, but they are often limited to verbal descriptions and illustrations in a textbook. What is missing is the potential that technology has in making mathematics and science come alive for the student and become relevant to their interests and experience. Science and mathematics can be integrated with technology using the *theme* and/or the *technological problem* as the means of integration.

REFORM OF SCIENCE, MATHEMATICS AND TECHNOLOGY (MST) EDUCATION

Reform in technology education related to MST integration in the elementary school primarily began with a thesis of how and why industrial arts should be used as an integrating thread throughout the elementary school curriculum. Industrial arts not only taught elementary school students about the occupations of industry, it was also seen as a method to teach arithmetic and science among other school subjects (Bonser & Mossman, 1923). This idea, fostered by John Dewey's progressivist influence, had a powerful and lasting effect on how industrial arts was taught at the elementary school level.

The next widely recognized relationship among technology, science and mathematics was realized in a curriculum developed by William E. Warner and others in 1947. Their curriculum framework, completed after World War II, emphasized a general approach to the study of the technology of industry. The study of modern manufacturing and communication (among other areas) contrasted with the traditional unit-shop approach of teaching students metalworking, etc., and this *Curriculum to Reflect Technology* recognized that modern industry was dependent on science and mathematics (Starkweather, 1979, p. 78).

Olson took Warner's ideas further and proposed that the content of industrial arts should be derived from the analyses of technology (Martin & Luetkemeyer, 1979, p. 37). Olson (1972) helped popularize the belief that industrial arts was the interpreter of technology in general education. His work in curriculum development could be characterized as the foundation that fashioned industrial arts content into what is related to science and mathematics *per se*. Olson (1963) added areas of technology study to the new curriculum that were interdisciplinary in nature. Industrial research, the work of the chemist, and the role of mathematics in scientific research are examples of these areas.

Since the 1950s, Maley and contemporaries were reforming the methods of instruction and creating acceptance of interdisciplinary instruction and curriculum integration. He wrote about the need for industrial arts content and instruction to be relevant to the interests and concerns of the students (Maley, 1972). He recognized that industry is based on science and mathematics and that industrial arts could improve science and mathematics instruction by teaching their applications (Maley, 1959). He motivated industrial arts teachers to coordinate their efforts with other teachers in their schools.

Major curriculum efforts since the 1950s aided in emphasizing the breadth of technology as a content base, which emphasized science and mathematics in kind. By virtue of its national acceptance, the Industrial Arts Curriculum Project (IACP) helped establish modern industry and its technology as a content base for industrial arts. IACP particularly emphasized the use of science and mathematics used in the research and development activities of manufacturing and construction (e.g., Lux, 1971; Ray & Lux, 1970).

Maley's (1973) *Maryland Plan* was also a logical next step to the emphasis on technology, and it is significant in that the curriculum emphasized research and experimentation. Maley placed great emphasis on applying science and mathematics to technology.

Next, the *Jackson's Mill Industrial Arts Curriculum Theory* (Snyder & Hales, 1985) and *A Conceptual Framework for Technology Education* (Savage & Sterry, 1990) placed considerable emphasis on the relationships between technology and science. Four curriculum projects that extended into the early 1990s helped to give MST integration greater, more important status. PhysMaTech (Scarborough & White, 1994) and Integrating Math, Science, and Technology (IMaST) (Loepp, 1992) are course curricula that help teachers implement MST integration by providing curriculum content related to the three areas. The Technology, Science, Mathematics Integration Project (LaPorte & Sanders, 1993) developed curriculum integration activities for the middle school that strongly emphasized the correlation of instructional activities within each of the three classrooms. Finally, Mission 21 (Brusic, Barnes, Dugger, Dunlap, & LaPorte, 1988) developed curriculum activities that integrate all elementary school subjects with technology.

Zuga (1984) provided insight into the disposition of educational reform in the late 1970s and early 1980s. She contended that the reforms ran contrary to the progressivist approaches and methods of technology education. The back-to-basics movement placed limited emphasis on learning through experience and activity, let alone curriculum integration. The focus was instead on test scores and knowledge of a prescribed amount of content. She also was astute in pointing out the void in research in elementary school technology education (see chapter 12) and made an argument that ESTE curriculum integration should proceed based upon a philosophical foundation.

The Technology for All Americans (TAA) project is currently developing national curriculum, evaluation and professional standards for technology education, K-12. At the time this chapter was written, TAA was in phase one of the process that included identifying the content domain of technology education (Dugger, 1995a). Two of its initial conclusions are that curriculum integration should be most widely used at the elementary school level and that content should be less specialized (Dugger, 1995b). In phase two, TAA will develop standards that span K-4 and 5-8 and that pertain to technology education, science, mathematics and engineering education (Dugger, 1995a).

Recent reform in science education

A 1988 report of the International Association for the Evaluation of Educational Achievement (IEA) presented the results of science achievement testing in 17 countries. For 10–year-olds, Japan and Korea ranked first, and the United States ranked only eighth (pp. 2-3). The results were even worse for the U.S. at the secondary school levels. The IEA's comment on the state of science education in the U.S. reads in brief, "For a technologically advanced country, it would appear that a reexamination of how science is presented and studied is required" (p. 9).

Project 2061 (AAAS, 1989), published in 1989, was principally concerned with science education. The project reviewed the state of education in the United States and recommended changes and implementation strategies for science, mathematics, technology and other areas of education. The recommendations are contrary in many ways to the back-to-basics movement cited by Zuga as a hindrance to reform.

In completing Phase I of the project, several important problems were identified. They include antiquated methods of science instruction and lack of student motivation manifested by these methods. The project revealed that science and technology instruction were all too often descriptive and provide little opportunity for students to apply mathematics to the analysis of science and technology. Elementary teacher preparation is cited as being inadequate in science and mathematics, and existing textbooks are described as leading to descriptive learning and the memorization of unrelated facts (Johnson, 1989, pp. 13-14). "Ideally, the integration of mathematics, science and technology will emerge in the future curriculum from hands-on experience generated by students' interests under the guidance of expert teachers" (Blackwell & Henkin, p. 31).

Project 2061 (AAAS, 1989) recommended that science, mathematics and technology be integrated as much as possible. Its authors suggested that the instructional methods and hands-on approach of technology education instruction make it a key partner in interdisciplinary curricula and instruction. By the end of Phase II of the process, the project (AAAS, 1993, p. 320) had identified three aspects of curriculum integration that were believed to be key to success: (a) planning integrated curricula should include real and interrelated participation by all teachers in a school as opposed to teachers simply planning the related topic within the realm of usual practice; (b) curriculum integration should allow students to identify the relevance of what they are learning via the interconnections of the content and activities and; (c) the culminating result of curriculum integration should be a broad picture of science, mathematics, technology and other subjects instead of simply a collage of disconnected concepts.

The Phase II process yielded "benchmarks" for structuring the process of developing scientific literacy. One such benchmark is "The Nature of Technology." These benchmarks include the broad understandings and skills students should have from kindergarten to the fifth grade (AAAS, 1993, p. 41). "The Designed World" includes elementary school benchmarks in technology related to manufacturing, energy and communication, among others (p. 181). In addition, the benchmarks of "Common Themes" include those broad concepts that overlap with the sciences, mathematics and technology (p. 261).

A second important science reform project is under development by the National Committee on Science Education Standards and Assessment (NCSESA, 1994). Through standards they are developing, they intend to be more directly focused on the characteristics of student proficiency in science (p. 1), and they will specify assessment and professional development standards. Tentatively, the NCSESA standards for the elementary school-grades will be divided into two grade levels: K-4 and 5-8.

Science-Technology-Society (STS) Roy (1990) characterized the STS approach to learning as a social-problems focus that incorporates hands-on learning. Gilliam, Helgeson and Zuga (1991) described STS as an emerging multidisciplinary field of scholarship that is finding its way into the public schools and higher education. This educational "infant" provides the opportunity for the integration of science and technology in a sociological context. Its chief rationale is a recent recognition that students fail to understand the relationships among science, technology and the modern society (Kranzberg, 1991). Such an understanding is considered vital. STS considers the fundamental contribution of technology education to be its tradition of hands-on practice.

While the application of STS in the elementary school seems like a promising area of innovation, in practice the approach provides a strong emphasis on social science as opposed to technology. Relatively few technology educators have participated in developing STS curricula (Sanders, 1990), yet its application to the elementary school seems like a promising area of innovation. An elementary school STS curriculum resource developed by Bybee and Landes (1988) calls for very little real hands-on technology activity and reinforces the notion that technology education has a great deal to offer the movement.

Recent Reform in Mathematics Education

In 1989, the National Council of Teachers of Mathematics (NCTM) published standards for mathematics curricula, assessment and professional development that were the result of reform by their Commission on Standards for School Mathematics (1989). They recognized that traditional approaches to mathematics instruction were out-dated. The commission stated that too often, mathematics learning had been a passive undertaking and should be an active process of "doing" mathematics in the context of living. They recognized that the technological nature of contemporary life has placed more importance and caused more dependence upon mathematics than in the past.

The Commission developed standards for the elementary school grades grouped K-4 and 5-8. These standards focused less on precise concept attainment and more on the *process* of concept attainment. The first four broad groups of standards emphasize the importance of problem solving, communicating, reasoning, and the relationships among subject areas. The commission recognized the benefits of curriculum integration with other school subjects, including industrial technology education (p. 86). "The curriculum must give students opportunities to solve problems that require them to work cooperatively, to use technology . . . and to experience the power and usefulness of mathematics . . . Real-world problems are not ready-made exercises with easily processed procedures and numbers" (pp. 75-76).

Prior to the influence of the NCTM standards, the field of mathematics education recognized the need for concrete instruction at the elementary school. The use of manipulatives and technology in elementary school mathematics education has been a major reform effort for several decades. The use of manipulatives in the mathematics classroom is a relatively popular approach to instruction. The fact that there is significant research on the effectiveness of mathematics manipulatives not only has implications for hands-on instruction in technology education, but it also underscores a major commonality between mathematics and technology education: appreciation of hands-on instruction. In contrast, *technology* usually means calculators and computers to mathematics teachers, which demonstrates the need for communication and collaboration among mathematics and technology educators.

In the spirit of reform, a number of science and mathematics integration curriculum projects have developed materials for the elementary school classroom. Among the more significant projects are the Science Curriculum Improvement Study (SCIS), Science: A Process Approach (SAPA), Unified Science and Mathematics for the Elementary School (USMES), South Central Kansas Elementary Math-Science Project (SOCKEMS), and Teaching Integrated Mathematics and Science (TIMS). Most of the major projects are supported by quasi-experimental research showing the significance of their treatments. The School Science and Mathematics Association (SSMA) periodically publishes a bibliography on curriculum integration (Berlin, 1989). This bibliography is a service to educators who want access to the relatively few good quality curriculum materials that address their classroom needs.

Status and Issues of MST Integration at the Elementary School

Reading literacy, the integration of reading and writing, and whole language are prevalent areas of innovation in the elementary school. Science education at the elementary school level is almost totally dependent upon the use of the textbook, and very little instruction focuses on how to read science texts (Harms, 1980; Yore, 1986). Because the use of textbooks seems less effective, elementary school teachers are integrating reading and science (Lapp & Flood, 1993, p. 71).

Many examples of "mathematics, science, and technology (MST)" are found in children's novels and other resource books. Novels and other books and resources provide a variety of in-depth points of view into the subject matter that tend to interest students and motivate them to learn more (Lapp & Flood, 1993, pp. 71-72). The integration of literature and mathematics is also seen as an approach that circumvents the problems associated with memorizing mathematical facts without purpose. The literature provides context (Braddon, Hall, & Taylor, 1993, pp. 3-4). The use of children's literature to integrate subject matter has recently included technology education. Using Novels for Interdisciplinary Technology Education and Science (UNITES) is a recent example of integrating reading with MST, among other elementary school subjects (Ney, 1994).

While the use of literature to integrate instruction and curriculum is a powerful inroad for technology education, the reality is that literacy in reading, mathematics, and social studies occupy the principal focus of instruction, time and other resources at the elementary school level. There exists a number of additional reasons technology and science in the elementary school are still among the "outsiders" (Tilgner, 1990, p. 421; Kieft, 1988, p. 27). Chief among them are the lack of

- preservice elementary school science teacher education and inservice training that results in textbook dependency (Mettlefehldt, 1985, p. 68; Mullis & Jenkins, 1988, p. 91);

- preservice elementary school technology teacher education or experience in technology (Daiber, Litherland, & Thode, 1991, p. 189; Kieft, 1988, p. 27; LaPorte & Sanders, 1995);
- equipment and supplies (Teter, Gabel, & Geary, 1984);
- facilities (Teter, Gabel, & Geary, 1984); and
- funding for all of the above (Tilgner, 1990, p. 421; Kieft, 1988, p. 27).

There is a link between the attitudes students establish in elementary school and how they perform in the secondary school. Generally, students are less interested in science and mathematics than they are in other subjects by the time they enter secondary school (Raizen, 1982, pp. 4-5). An Educational Testing Service report on students' attitudes toward science reported that 71 percent of third-graders believe that science will be useful when they grow up. Only half of seventh-graders and even fewer eleventh-graders believed that science would be relevant to their lives as adults (Mullis & Jenkins, 1988, p. 126). Mittlefehldt (1985, p. 67) characterized the American student as being intimidated by secondary school science.

In response to declining enrollments in science courses at the high school level, Boyer (1983, p. 107) made a specific recommendation about the minimum amount of science courses students should take. He made two points about secondary school science enrollment. Society should be less concerned about how much science students are taking and more concerned about the quality of the science (pp. 83-84). He stated that science "should be taught in a way that gives students an understanding of the principles of science that transcend the disciplines" (p. 107). Boyer also emphasized the importance of making common sense connections between mathematics and real life through practical problem solving (pp. 108-109). As remedies, Boyer recommends that teachers should focus quality mathematics and science lessons on principles and practical problem solving and that this focus should be implemented beginning in the elementary school.

Fort (1990, p. 670) wrote that elementary school students receive a "rudimentary" experience in science because their teachers are poorly prepared to teach it. While only seven percent of elementary school teachers surveyed reported that they were certified in science, 63 percent of middle school science teachers and 80 percent of high school science teachers were certified in science (Mullis & Jenkins, 1988, pp. 91-92). There seems to be little chance for students to discover whether or not they have a genuine interest in science.

As a result of this missed opportunity, Fort characterized secondary-school students as being "science shy" and "unprepared." She cited among other causes the lack of direct hands-on experiences for elementary school students in science and their teachers' dependency on textbooks (p. 670). In contrast, Brusic (1991) found that fifth-graders' curiosity about science increased when hands-on technology education activities were integrated into science instruction. Teter, Gabel and Geary (1984) surveyed elementary school teachers on how to improve science instruction. The use of hands-on instruction was much less popular than the use of textbooks in the fourth through sixth grades. They found that teachers placed a low priority on teaching with science equipment and teaching scientific processes. Teachers wanted ready-made lesson plans and readily available science kits.

Mittlefehldt (1985) acknowledged that science is excluded in the elementary school due to time constraints, among other problems. He recommended that interdisciplinary arrangements allow elementary school teachers to continue teaching what they know well (arts and humanities) and realistically provide science instruction in the context of what they usually teach. He states, "This interdisciplinary flexibility begins to reflect the role science plays in society and is simultaneously compatible with the elementary school teacher's orientation" (p. 69).

Similar constraints exist for technology education at the elementary school. In a 1964 study, Bruce found that industrial education courses were available to preservice elementary school teachers in 94 of 165 institutions he surveyed but that very few elementary school teachers received formal instruction in the subject.

Girish (1993) concluded that preservice elementary school teachers who enrolled in an integrated MST course recognized the potential in using hands-on problem solving and cooperative learning. Most importantly, they felt capable of implementing MST integration.

Few elementary school technology education programs are implemented in the form of courses. Rather, they are generally delivered as part of an interdisciplinary approach mainly due to the constraints cited above (Zuga, 1988, p. 60). However, the best role of technology at the elementary school level may be as an integrating thread throughout the curriculum (Zuga, 1988, p. 60; Daiber, Litherland & Thode, 1991, p. 189; Peterson, 1986, p. 49).

Ideally, elementary school students need to learn technology content, so ideally, elementary school teachers should avoid using technology education solely as a method of instruction. The real power behind the curriculum base for technology education—the power that allows it to work well at the elementary school level–but is that it is a spiral curriculum based on themes. To suggest that second-graders learn about tools, third-graders learn about automation, and fourth-graders learn about lasers should serve only as a suggestion as to how a school may organize the study of technology using the thematic approach.

Much of the elementary school industrial arts education literature was directed at the intellectual domain of the study of the industrial content base. There are also contemporary treatments of technology content for curriculum development (Peterson, 1986, pp. 53-55; Daiber, Litherland & Thode, 1991, pp. 192-196). Such approaches to ESTE curriculum development seem preferable to less-structured approaches. However, the highly structured approaches to curriculum development seem more suited to the development of elementary school technology education curriculum projects, such as Project Open (Peterson, 1980, p. 15) and Mission 21 (Brusic, Dunlap, Dugger, & LaPorte, 1988, p. 23). They seem less suited for the average elementary school teacher trying to correlate curricula within a theme that includes technology.

Many educational programs are competing for space in the elementary school and in elementary school teacher education programs. Reformers in science education believe elementary school teachers need more college science. Technology education reformers believe elementary school preservice teachers need technology education. The reality is that only those technology content areas that relate to the currently established elementary school curriculum are those that teachers will present to students. The content presented in the elementary school should be presented on a "need to know" basis (Daiber, Litherland, & Thode, 1991, p. 189). The technology content is that which fits with what is being studied in the other areas of the curriculum.

Rationale for Curriculum Integration

The rationale for curriculum integration is strong but not always obvious. Primarily, subject matter relevance is a direct and widely-cited reason for curriculum integration. Subject area isolation is eliminated when students see the application of the content of one subject within the context of another subject. The student sees reasons that the content is necessary to learn (Dewey, 1917, p. 157; Boyer, 1983, pp. 114-115). An arrangement where the long-term focus is more on broad concepts and principles and less on facts and will facilitate the transfer of knowledge (Bruner, 1977, p. 31). It is useful to focus on the methods of inquiry and the connections among the disciplines represented (Jacobs & Borland, 1986, p. 161).

Discovery and understanding of the symbiotic relationships among subject areas is another way of stating this rationale (LaPorte, 1994, p. 211), which imparts a sense of utility. Maley (1959, p. 12) argued that in order to understand technology, the student must also understand science and mathematics, among other subjects. The multidisciplinary nature of the practical problems students seek to solve in technology education requires understandings outside the discipline of technology (Maley, 1992, p. 10).

Improving student achievement is another reason to integrate curricula. However, many studies in elementary school curriculum integration do not show significant student achievement based on their treatments. Nonetheless, such studies are informative. Cook and Campbell (1979) stated, "A case can be made . . . that external validity is enhanced more by a number of haphazard samples than by a single study with initially representative samples . . . " (p. 73). They stated that field-based research "is more one of generalizing across haphazard instances where similar-appearing treatments are implemented" (p. 73). The following studies seem representative of the limited research directly related to technology, science and/or mathematics integration.

Bruce (1964) compared the mathematics and science achievement of six classes of third-grade students and six classes of fifth-grade students that received integrated mathematics and science instruction (in its true form), six classes at each grade level that received integrated instruction that was correlated and six classes at each grade level that received traditional subject-oriented instruction in mathematics and science. There were not significant differences among the three groups at either grade for mathematics achievement. Lower-ability students in two of the treatment groups achieved greater gains in science than higher-ability students. These results suggested that true mathematics and science curriculum integration and curriculum integration in the form of correlation may be effective in improving the science achievement of elementary school students who are assessed at low-ability levels.

Brunk and Denton (1983, pp. 43-44; 46) compared the conceptual understandings in music, science and social studies of 317 first-graders who received integrated instruction in the three subjects and the conceptual understandings of 102 first-graders receiving traditional subject-oriented instruction. Statistically significant differences in understandings were found in favor of the treatment group for science, social studies and music. The results suggest that first-graders may benefit from integrated curricula.

Shann (1975, pp. 1-3; 8) reported the results of a study measuring the effects of the Unified Science and Mathematics for Elementary Schools (USMES) curriculum instructional units. Thirty-seven treatment classrooms were compared to 34 control classrooms. Control groups received traditional, subject-oriented instruction. On average, treatments were administered one and one-half hours daily, three days a week for 12 weeks. Dependent variables on pretests and posttests were basic academic skills and problem-solving ability. While students were said to be excited with the treatment, no statistically significant differences were found. Shann concluded that the USMES curriculum materials did not inhibit student growth in basic skills.

Brusic (1991, pp. 69, 72) compared the science achievement and scientific curiosity of 58 fifth-grade science students who received science instruction integrated with a technology education activity (treatment) and the same effects on 65 science students taught without the technology activity (control). The treatment was administered for an average of almost five and one-half hours over a 10-day period (p. 89). There were no significant differences between the groups in science achievement (p. 139). However, there was a significant difference in the curiosity measure in favor of the treatment group (pp. 141-142). Brusic's findings suggest that the integration of technology education activities with another subject may be ineffective for improving achievement as a short-term treatment but adequate at improving curiosity.

Problem-solving and technological development have long been established instructional practices in technology education. Lux (1984, p. 18) concluded that the practices of technology and instruction in technology education should be couched in a theoretical foundation. To simply "make and do" was not to have an understanding of technology. Participating in technology is essential. Integrating technology education with other subject areas enhances the student's understanding of technology. The weaknesses of science education in failing to teach application are offset by the teaching of technology, and technology instruction is strengthened by the theoretical foundation of science (Lux, 1984, p. 20), as well as mathematics. Zuga (1988, pp. 65-66) concurred, implying that curriculum integration at the elementary school level is an effective way to reinforce various subjects, including technology education. The student might study a science concept and then have the opportunity to apply it in the study of technology or *vice versa.*

Roth (1993, p. 113) compared cognitive constructivism to the traditional practice of "transmitting" knowledge from the teacher to the student. As an extension of Piaget's theory of cognitive development, cognitive constructivism holds that students construct knowledge through experience. This experience makes one person's understanding of a concept different from another person's understanding. Students assimilate what is experienced with previously held understandings. If the experience differs from a learner's expectation then conceptual understandings are changed in the learner (von Glasersfeld, 1987, pp. 14-15).

Placing this necessary experience in the context of the discipline provides opportunities for authentic practice (Roth, 1992, p. 308). Because ESTE extensively involves hands-on activity and application, its integration provides opportunities for students to construct their own knowledge, extending the relevance of subjects to the student. Such an arrangement would also extend the opportunities students have to explore their interests in science and technology before their secondary education commences. Technology activities can be the context in which students engage in authentic practices in technology, science and mathematics.

Finally, curriculum integration is an effective way to include various subjects in the overcrowded elementary school curriculum (Jacobs, 1991, p. 24). This is an approach science education is also using to get a better foothold in the elementary school (Mittlefehldt, 1985, p. 69). Having no previous exposure to technological concepts, a teacher may not include them in his or her instruction, but teachers who have previous experience with technology education tend to self-initiate units of instruction that include technology education (Kieft, 1988, p. 27).

APPROACHES TO MST ELEMENTARY SCHOOL CURRICULUM INTEGRATION

To describe the approaches to MST elementary school curriculum integration, one must build from fundamental considerations toward the details of a suitable instructional model. Among the considerations are the short- and long-term purposes of curriculum integration, the structure of the school curriculum, the relationships among the subject areas being studied and the approaches to instruction.

Horizontal and vertical integration of knowledge

Tyler (1958, pp. 112-113) explained that integrated curricula should be organized around concepts, skills or values (as opposed to memorized facts). An integrated curriculum should provide horizontal integration of learning and assist in the student's integration of knowledge throughout his or her schooling. He characterizes this integration throughout the school career as "vertical integration." Any specific concept, skill or value is worth teaching if it aids in these two integrating functions.

Transportation technologies are concepts that meet Tyler's criteria. In the early elementary school grades, children study how family members drive cars or use the bus for important reasons. Many of these forms of transportation utilize vehicles that are designed for specific functions. In mathematics, students may understand that there is a relationship between the number of busses that come to school every morning and the number of students who attend the school. And in science, students learn that certain forms of transportation are designed to adapt to the requirements of nature (such as rubber tires for traction or suspension systems to carry the busses over variations in surface conditions). Through observation and deduction, they might hypothesize that were school busses not made strong enough, they could not carry many students or that if they did not have springs, they would provide a rough ride. Such a curriculum arrangement serves to horizontally integrate technological, scientific and mathematical knowledge within the student.

The spiral curriculum and integration

Lauda (1983) described the spiral nature of technology education curriculum. The spiral design of the technology education curriculum allows elementary school students to become aware of transportation technology and its influence on their lives. Carrying the transportation example above to the next level, middle school students might explore transportation technology and how it influences the world. High school students might study transportation technologies to a higher degree of specificity. The fourth-grader's understanding of transportation technology is more sophisticated than the first-grader's. This spiral curriculum is a structural consideration that is necessary for the vertical integration of knowledge within the mind of the student.

The spiral curriculum is also important in the facilitation of problem solving. Reformers from technology education, science and mathematics recommend that students learn primarily through problem solving and other means that involve activity on the part of the student. They recommend that the content be important to both the learner and society (Johnson, 1989; Blackwell & Henkin, 1989). When students progress from one problem to another, some skills and concepts that are important for solving one problem may not be important for the next.

Traditionally, mathematics has been a highly sequenced, subject-centered curriculum (Taba, 1962, pp. 177-181). Third-graders learned about multiplication, fourth-graders learned about fractions, and tenth-graders learned about geometry. Contemporary thinking about the spiral curriculum is breaking down such rigid structures so that students can learn the elements of what they need to know to solve practical problems called for by a particular situation. An elementary school student may never learn a simple geometrical concept because it is taught in the tenth-grade even though it is important to him or her in the elementary school. As Taba (1962) stated, concepts "cannot be isolated into specific units but must be woven into the whole fabric of the curriculum and examined over and over again in an ascending spiral" (p. 178).

Convergence yields themes for instruction

Some educators are concerned that there is presently an overemphasis on the integration of mathematics, science, and technology and that much of the motivation is political (Foster, 1994, pp. 76-77). Despite any trivial reasons for the integration of mathematics, science, and technology as contemporary disciplines, they are natural partners due to their epistemic structures. From a contemporary perspective, Dugger (1994, pp. 7-8, 20) described the relationship among the three as a symbiosis: each has its own function in fulfilling the needs of humans and each also serves as a language and a tool for the others.

This description has implications for the approach one takes to MST integration. The concepts, skills and values that Tyler held as important to the formal education of students are often different for each discipline represented in the schools. But many of the important concepts are interfaced as needed into themes for instruction. Perhaps it is this flexibility that makes themes a widely used approach in the integration of technology education with other subjects (Perusek, 1980, p. 47; LaPorte, 1994, pp. 210-211).

At the most basic level, curricula can be correlated among teachers, completely integrated under one teacher or combined in some degree into special courses with one or more teachers (Van Til, Vars, & Lounsbury, 1961, pp. 90-96). Different variations of these three basic approaches are described throughout the literature. For example, LaPorte (1994, pp. 210-214) distinguishes interdisciplinary approaches from integrative approaches. While both approaches capitalize on overlapping, related or common content, the interdisciplinary approach focuses instruction around a central project or undertaking. The integrative approach does not. Jacobs (1989, pp. 15-18) elaborated upon an exhaustive number of variations to integrated approaches and curriculum models.

In the early years of a student's elementary schooling, he or she may have the same teacher for all subjects (self-contained), and starting as early as the second or third grades, he or she may have different teachers for different subjects. In both circumstances the use of themes is viable.

One important assumption of the process of curriculum integration is that the teacher has a clear understanding of what general curriculum goals and specific curriculum objectives are necessary for rigorous student learning. Theoretically, a theme is identified based on these goals and objectives. All planning and instruction by the teacher is rooted in these goals and objectives. Knowing what concepts students need to learn, the teacher could develop a theme around the necessary content.

Within the scope of the theme, students may have input into content selection. In the self-contained classroom the single teacher could have students brainstorm questions they have about the central theme (Perusek, 1980, pp. 44-46), such as transportation in the community. A web of questions and ideas is developed around the theme and used to guide the next stages of instruction in the thematic study (see Figure 1). The web is not only useful for identifying strong relationships among the subjects, but it also helps the teacher identify additional related subjects, such as social studies, as well as distantly related subjects.

The elements of the web can be organized into groups of ideas and questions that are similar, and less-related questions and ideas can be saved for future learning (Perusek, pp. 46-47). Taba (1962, pp. 302-303) provided an example of the logic used to conceptualize the relationships among the content of the various disciplines. She used an example in which the curriculum objective is understanding life in South America. The teacher needs to decide which approach for organizing the interrelated content will provide a learning focus on the primary concepts. If learning about the different aspects of life is more important than the various contexts

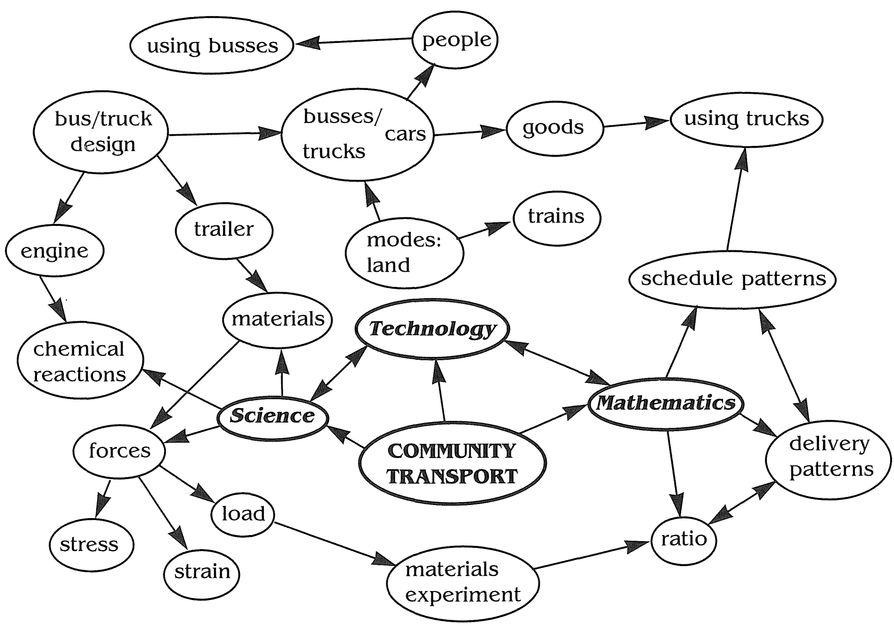

Figure 1 *Webbing is a process for planning integrated content or skills initially.*

provided by different South American countries, then it may be more important to study the government, economy, religion, etc. in one country. Conversely, if the geographical settings are more important, then the teacher might prefer to teach one aspect of life, such as government in several South American countries. Activities are based on the web. This approach avoids the common and haphazard practice of first deciding what the activity will be and only then identifying the student outcomes (Bensen, 1980, p. 12).

Some ideas about the transportation theme may also be related to mathematics. Why do some busses get to school early and why do some busses get to school later? Some ideas about the theme may be related to technology. Why do the trucks that come to the school cafeteria look so different? Some ideas might be related to science. Why do large trucks have more wheels than small trucks? The process blends what students want to know with what students need to know.

At this point, the teacher has the choice of blending the three subjects into one episode of instruction. Alternatively the science content can be studied by the class for some period of time, followed by the technology, which would be followed by the related mathematics instruction. In either case, the teacher can further plan by developing a staircase of the technology, science and mathematics concepts that outlines the integrated content and skills in greater detail (Zuga, 1984, p. 38); as illustrated in Figure 2. From this staircase the teacher gets a better idea of what activities will best facilitate learning. If there are not specific prerequisites to studying elements of the theme, there may not be a particular or critical sequence to the instruction and activities.

Based on curriculum and student objectives and on the details of the staircase, the teacher facilitates learning in the theme through instructional activities he or she designs. Students can be assigned questions to solve and ideas to explore through hands-on activities based on their interests and may work individually or in small groups (Perusek, p. 47). Some of the activities may focus more on concepts from one discipline than on concepts from the others, but skills and concepts from all three disciplines will be needed to some extent.

In the transportation example, the teacher could help one group of students plan a strategy for answering the question about bus arrivals. They might record when each school bus arrives at school each morning and observe that bus 233 is always first, bus 453 is usually second and so on. In doing so, they are fulfilling mathematical curriculum objectives—in this case, assigning rank or order.

Through their observations and record-keeping, students may be fulfilling science requirements. Students may have developed a hypothesis that some busses carry students that live close to school and others carry students that live far from school. If the group asks students from different school busses where they live, they could conclude that the first bus arrives early because all of the students who ride it live close to the school. They are using a science skill to ascertain a mathematics concept of patterns.

Community Transport

I. Technology

- A. People
  - 1. student travel
    - a. school busses
    - b. bicycle, foot, cars
  - 2. parent's travel
    - a. cars to work/store
    - b. busses
    - c. trains
- B. Goods . . .

II. Science

- A. Designing materials experiment
- B. Chemical
  - 1. engine fuels
  - 2. pollution
- C. Physical
  - 1. stress . . .

Figure 2 *The staircase is a process for more detailed planning of integrated content or skills.*

Themes could also be used in the higher elementary school grades. In the elementary school, there may be a resource person assigned to teach subjects such as technology education (Etchison, 1994, p. 31), science, music, etc. Science and technology education could be integrated into one class much as music and art are sometimes combined. The mathematics teacher and the teachers (or teacher) responsible for science and technology education can use the web to identify areas of overlapping content (Levy, 1980, pp. 26-27). The teaching team could plan the web together, develop staircases individually and get together again to decide on appropriate activities.

Instruction in the two or three classes may be correlated to coincide or may be delivered in a particular sequence. At the same time mathematics students are using fractions in their study of bus-use patterns, they are studying observation, recording, and hypothesizing in science. Later in the sequence, the technology teacher helps students understand that some trucks delivering food to the cafeteria need to refrigerate the food they carry and others carry canned food, which does not require refrigeration. Through further study, students identify other reasons trucks are designed differently. They may use their research and understanding to design and build models of the types of trucks necessary to keep their community running smoothly.

At about the same time in science, they may study the reasons some trucks have more wheels than others. Through the use of fractions and linear measurement, students cut boards that represent different size trucks. Small pieces of Styrofoam are used to simulate wheels. Four "wheels" are placed under the small "truck," and it is loaded with one layer of as many weights as can fit on it. Next, the students hypothesize whether the same number of wheels will support as much weight as can be loaded onto the large "truck." Students may apply mathematical concepts of charting and graphing to represent the results of their experiment. Students may apply this new understanding in technology education and design truck models with a sufficient number of wheels.

In both the self-contained and correlated examples, the arrangement provided for the horizontal and vertical integration of knowledge. Even though the skills and concepts become more sophisticated, they are broad enough and important enough to be transferable. The spiral curriculum allows students to apply fractions instead of rank/order to the study of bus use patterns at their school. Revisiting important ideas in science and technology facilitates the application of experimentation and design to more detailed applications. MST integration does not require a stretch of the imagination. The content and skills of one discipline complement and facilitate learning in the other areas. Authentic practice in the three disciplines is reflected by the activities conducted around the theme within each subject and is facilitated by the integration. While it would be inappropriate for elementary school students to build trucks, it is appropriate to build models. The fact that their model trucks were based on design requirements (e.g. more wheels increase capacity) makes the learning more authentic. The same parallel could be developed about the authentic application of mathematics and science.

The transfer of learning, the relevance of the curricula and the opportunity to construct knowledge were facilitated by several aspects of these integrated units. The fourth-grade students, having studied transportation in the first or second grade, appreciate that understanding now that they are studying it in more detail. As they transfer their learning from one grade to another and one class to another, they develop an appreciation for why they need to know the content. And because the study is related to their community and they have the opportunity to try their hands at research, calculations, experimentation, and model design and construction, they have the opportunity to construct their personal understandings of the content.

Finally, the higher degree of true integration in the early example is more theoretically promising in terms of relevance and continuity for the learner. Subject-segregated correlation is theoretically less desirable but often required within the constraints of the school (Beane, 1990, pp. 15-23). Where possible, the teachers of separate subjects could be assigned to team-teach their content in a block of time (LaPorte, 1994, p. 214). When the resources are available for team teaching, every effort should be made to truly integrate the content. Too often, team teaching becomes subject-centered instruction, the only difference being that the subjects are taught in the same classroom.

INTEGRATING PROBLEM SOLVING INTO THE APPROACHES

Mission 21 (Wells, LaPorte, Dunlap, Dugger, & Brusic, 1992) materials are a good example of technology activities that integrate elementary school subjects. Each Mission 21 activity is designed for a particular set of elementary grade levels, and each is problem-based. Each activity begins with a design brief that provides students with a description of a practical problem that is solvable in part by applications of technology, science and mathematics. It describes this technological problem in the context of a real-life situation, outlines the constraints under which the students will work and often describes how the solution should be evaluated.

The process of applying technology to solve practical problems is referred to as *technological problem solving*. While there is still debate as to whether technology is characterized by one particular method of inquiry (Israel, 1992, p. 13), technological problem solving is a major approach to experience-based learning in technology education. The process is not only an interesting way to learn about technology and applications of science and mathematics, it fosters creative thinking. Like the engineer, the technological problem solver develops divergent thinking in conceptualizing problem solutions and convergent thinking in implementing them (Dugger, 1994, p. 20).

The problem-solving approach to MST curriculum integration is a good way to develop activities based on identified objectives, webs and staircases. However, this approach may require that certain key concepts, those important to the solution of the problem, be taught in a particular sequence (Thomas, 1986, p. 59). In keeping with the theme of transportation in the community, the following might be a good problem. "The cafeteria in your school needs a lot of food to make lunch. The people who deliver food there need a truck that is able to carry a lot of food. To do that, the truck has to be big enough to hold all the food and strong enough to support the weight of the food. Find out if your teacher's model truck is big enough and strong enough to hold and support all of the food. If it is not large and strong enough, design and build a model truck that will hold all of the food."

In planning for this technological problem-solving activity, the teacher will have to think of it as several activities within one. For example, he or she will need to facilitate the students' capabilities in planning how to decide if the truck is large enough. This activity might involve the science skill of experimentation previously described in working with the model trucks. Additionally, there may need to be supporting lecture, demonstration and/or time for student discovery. For example, students may not have done experiments before and need instruction and practice. Another consideration in planning technological problem solving is helping a group of students understand how to work cooperatively in thinking of possible solutions. Student research is a good approach to getting students to generate solution ideas, and the teacher will need to plan for this research.

Once students have synthesized their research, they will need the opportunity to implement their solutions. Here they may be applying the mathematics skills as described earlier, and they will certainly be working with tools and materials to try out their proposed solutions. Each of these undertakings require activity planning. Within the constraints of time and student interest, the students should have the opportunity to troubleshoot and improve the performance of their solutions. The key to technological problem solving within the context of MST integration is teaching students to use science and mathematics in developing their solutions. The key to planning for this is focusing on those science and mathematics concepts that students will likely need. Not only should the teacher focus on what concepts are needed but also on the sequence in which they need to be taught. Such planning and instructional design should be done within the framework of the overall curriculum goals and objectives.

EVALUATION AND ASSESSMENT OF STUDENTS

The methods used to evaluate student work in technology education are typically different than those used in traditional classroom-based school subjects. Therefore, it is necessary to review and understand these methods of evaluation and assessment. Wescott (1993, pp. 167-168) distinguished assessment from evaluation. Evaluation is a judgment of how well a student has met certain instructional or learning objectives. Assessment is a judgment of how effective instruction was in advancing a student's learning. Assessment can be thought of as a measure of where a student is on a continuum of achievement in some area of study. Another perspective in understanding assessment is thinking of it as a way of determining the educational needs of students. Evaluation, on the other hand, can be thought of as a measure of the degree to which a student has achieved a specific objective.

Evaluation involves four basic steps. First, the objectives-behavioral outcomes, or designed changes, in student behavior are identified. Second, the instruction that is referenced to the objectives is planned and delivered. Third, student progress toward the stated objectives is measured. Fourth, the results are used to improve instruction (Wescott, 1993, p. 168).

The measurement of the student's progress toward objectives can be accomplished in a number of ways. The teacher can test students, observe them or get them to write or report about themselves (Wescott, 1993). Gilberti (1992) stated that the construction of projects, student demonstrations and other activities are good alternatives to written, formal testing. No matter what methods are employed, the students should understand how they will be evaluated. Gilberti suggests that the use of a variety of evaluation techniques is the best approach.

Student Portfolios and Authentic Assessment

Portfolio assessment is becoming a popular form of student assessment in virtually all fields of education. The portfolio is a form of self-reporting. Collins (1991) stated that the portfolio should reflect the practices of the field that are relevant to the instructional objectives. For example, if a student is assigned a technological problem to solve with an objective to derive an awareness of problem solving in the way a technician, inventor or engineer practices it in the field, then the portfolio should provide evidence of this understanding.

If the portfolio represents true practices in the world outside the school, the portfolio becomes a means of authentic assessment. Mitchell (1989) stated that authentic assessment is characterized by the question, *Is this what we want students to know and be able to do?* (p. 5). Authentic assessment measures real practice, processes, understandings and knowledge of the field (Collins, 1991). The portfolio should reflect this purpose. It should reflect the grade level of the student, the disciplines and the interests of the student. Only key evidence of achievement should be included in the portfolio; it should not be confused with a notebook and become cluttered with every thought a student has during class (pp. 297-298).

Haertel (1991) stated that projects and laboratory activities tend to end with scorable products and artifacts. These end products should represent the results of practices and processes in the field. For example, in solving a technological problem, some student-built device may represent the solution or act to affect the solution of the problem. Subjective ratings of such outcomes is unavoidable, but objectivity can be added to the process by developing a rating scale and making sure students understand how the ratings are applied to their work.

Haury and Rillero (1992) outlined the evaluation of hands-on learning. One simple approach to evaluating student processes is asking the student why certain events are occurring. Next, if the objective is to apply mathematics and science principles, then the evaluation task or hands-on evaluation should require their application.

Bloom, Engelhart, Furst, Hill, and Krathwohl (1956, p. 125) stated that in measuring a student's ability to apply knowledge, the context of the problem should be different than that in which the knowledge was learned. Furthermore, the student's ability to synthesize the various parts of his or her solution, as well as the various science and mathematics principles, into the technological solution is important in determining whether a higher level of learning was achieved. In kind, the student's ability to evaluate or judge the value of the technological solution is another indication of the level to which students achieved. In providing iterations of problem solving (design, construct, test, redesign), the teacher provides the opportunity for growth at the synthesis and evaluation levels of learning. The evaluation of skills should not require traditional testing, and the scoring should measure performance (Haury & Rillero, 1992, p. 14).

RESOURCES AND CONSTRAINTS TO MST INTEGRATION

Except for cases of self-contained classrooms, the interdisciplinary team is virtually a requirement when curriculum correlation is to be implemented. Individual teachers bring their special knowledge to the planning process through teaming. The team allows teachers from the various subjects to sequence supporting instruction among their respective classes. However, difficulty in coordination among interdisciplinary team teachers is a common constraint to the integration process. Among the causes are a lack of commitment, lack of common planning, adherence to traditional methods of instruction, and rigid curriculum requirements. Several studies related to the integration of elementary school subject areas provided evidence suggesting experienced teachers have difficulty in transitioning their roles from lecturers to facilitators (Gillaspie, 1993; Kotowski, 1993; Guy, 1994). Another constraint to the entire curriculum correlation process occurs when the teachers don't all teach the same students.

From a broader perspective than previously outlined, overall MST program planning may proceed in phases. The first phase is characterized by the identification of common concepts, themes, etc. through webs and staircase plans. The second phase is the initial implementation of MST integration in the classrooms. This phase may be thought of as a pilot study. The novice curriculum integrator may limit the scope of implementation to maintain control and gain confidence. Teachers will evaluate student learning and the processes of planning and instruction. After making revisions to the process, the team may want to include MST integration on a regular basis and expand the scope of the units (Jacobs, 1991).

As previously stated, the elementary school teacher who is relatively unfamiliar with science (or technology) is typically textbook-dependent. Textbooks tend to contain ideas unrelated to the context of student learning and "cook down" or streamline knowledge, thus limiting the opportunities students have to relate to the real processes and values of the discipline (Lapp & Flood, 1993). Nonetheless, all teachers involved in the integration process need to gather a variety of reference and resource books and MST-related children's literature that provide a diverse, as well as a conceptually and contextually rich, perspective for students.

These resources also provide some technical content support for the teachers. Materials like *Mission 21* are excellent teacher resources because they may provide advice and guidance on the integration process while allowing for a multitude of integration contexts. However, one misuse of materials like *Mission 21* is that teachers may use the collection of technological problem-solving activities (i.e., "design briefs") as though they are the curriculum. These materials are designed to augment the curriculum, not to serve as the curriculum itself.

An additional means of technical and content support might be provided through the resource curriculum specialist or resource teacher for technology education. Though it is rare as of this writing to find such a person in a school system, there is evidence that it is a growing trend (see Etchison, 1994). This person is not necessarily the school system's supervisor for technology education. He or she could be a secondary school teacher who is knowledgeable in the field. Often secondary school technology education teachers will mentor the elementary school teacher and provide guidance in everything from what content is important to how to alter the classroom to facilitate technology education (Kieft, 1988).

There are relatively few ESTE programs that focus on technological content and process to the depth found at schools, such as Dranesville (Virginia) Elementary (see Forman & Etchison, 1991). Consequently, the prospective MST integrator may not be prepared in terms of tools and materials that would otherwise support optimal learning in technology and science. Equipment sharing and community resources are important means of support for the special needs of the elementary school technology and science programs (Mittlefehldt, 1985). Secondary school technology education teachers often share and exchange equipment among schools, and the elementary school program could investigate participating or making similar arrangements within the locality.

As mentioned in the introduction, today's ESTE programs do not depend on tools and materials to the extent they did when the content base focused on the technology of industry (see Bame &

Pinder, 1980), but classroom arrangements, tools and materials remain part of an optimal approach (LaPorte & Sanders, 1993). Johnson and Pine (1991) described an equipment-sharing program that facilitated teacher inservice training for teachers on the use and implementation of the equipment. The elementary school science teacher could benefit from such training (Mittlefehldt, 1985) as would the teacher responsible for technology. Elementary teachers not only need to learn the safe and efficient use of the tools and materials they share, but they also ideally need training on technology content. This training tends to lessen any dependence on textbooks and should provide teachers with the knowledge they need to maximize classroom space and the additional resources they have acquired.

SUMMARY

The time is ideal for the infusion of technology education into the elementary school and its nurture as essential learning for all. The science and mathematics communities have both developed curricular standards that clearly recognize technology as an essential part of the elementary school curriculum. These standards include the content of technology itself, as well as technological problem solving as a means to connect mathematics and science to the world outside the school.

Connecting disciplines together through integrating content continues to garner increasing attention in educational literature in general. The thematic approach that engages students in meaningful, real problems can integrate not only mathematics, science, and technology but also the entire elementary school curriculum. Given this integration and the transition from industrial arts, technology education can be integrated in the elementary school without a net gain in instructional time, dismissing the argument of content versus method. The principal focus of this chapter has been on using curriculum development strategies, such as webbing and stair-stepping, couched in the context of the spiral curriculum.

The technology education profession has responded in support of technology education at the elementary school level. Increasing numbers of presentations directed at elementary school curriculum and instruction are occurring at annual ITEA conferences. The Technology Education for Children Council has experienced growth and increased vitality. Increasing numbers of articles on ESTE are appearing in *The Technology Teacher.* The ITEA recently started Teacher of the Year and Program of the Year recognitions for elementary schools and teachers. Finally, the standards that are currently under development by the Technology for All Americans Project (Dugger, 1995a) include technology education at the elementary school as an integral part.

At the same time, the rest of the educational community remains engaged in turf battles, especially as they relate to the integration of mathematics, science and technology. Once an understanding has been reached on the battlefront, little is really known about how integration might best be done. Often, technology education is the "odd person out" simply because that it is typically an elective subject in the school.

Complicating this issue is the fact that the definition of technology education has not been universally embraced. At the philosophical level, educators seem to be starting to get their arms around it (although some would even argue this point to the contrary). However, at the curricular level, what educators are doing is akin to trying to embrace a ball of gelatin. The fact that some curricula are no more than tidbits rather haphazardly chosen from a smorgasbord of modules is but one indicator of a curricular problem educators have not yet solved.

It seems that the elementary school level is the place to invest our resources to achieve what many have sought for years: technology education to become an integral part of the educational experience of every student. If science and mathematics can be best learned by solving technological problems, teachers can learn this in the same manner as their students will. If elementary school teachers are natural integrators of curricula, then technology educators can learn from them. ESTE programs have almost always been developed downward from middle school and secondary programs. It is intriguing to think what might happen if technology educators discarded all of their current curricula and started from scratch, working our way up from the elementary school level.

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Chapter 4 Reading, Writing, and Technology

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The importance of literacy to an individual and to society is a common topic in academic circles and in the popular press. There is a shared belief that people need to be able to read and write. Isolating literacy as a discrete ability, however, obscures the many linkages between literacy, language arts, and other aspects of human learning.

Anthropologists, developmental psychologists, and sociolinguists all agree that people develop as they understand their environment through both physical and linguistic exploration. The fusing of physical reality with linguistic concepts forms the foundation for the development of abstract thinking and the basis for cognitive development. The child's ability to talk about the abstract—time, space and feelings—and things that are absent—past occurrences and memories—enables the child to use language in the development of higher order thinking. Language arts instruction acknowledges that oral and written language are not isolated subject areas but are comprehensive means toward experiencing, comprehending and expressing all facets of the child's world.

This chapter will emphasize that the acquisition of language mastery and the acquisition of technical understanding share common developmental and theoretical parallels—both are fundamental to children's construction of knowledge from the contexts in which they live. The following sections begin with an orientation to technology education and to language arts as taught in today's elementary schools. These sections are followed by an exploration of the linkages between language arts and technology and the integration of the two in fostering children's learning. A detailed description is included of how these linkages can be realized through elementary school technology education (ESTE) activities. Appended to the chapter are directions for a simple activity that illustrates the integrated teaching of ESTE and language arts.

AN OVERVIEW OF TECHNOLOGY EDUCATION

What is technology education and how is it included in the elementary school grades? First, let's look at what technology is: "technology is a body of knowledge and actions used by people to apply resources in designing, producing, and using products, structures, and systems to extend the human potential for controlling and modifying the natural and human-made environment" (Wright & Lauda, 1993).

This definition, written for an audience of technology teachers and teacher educators, needs further explanation and clarification for use here. First it is important to understand that technology is not simply hardware. Also, in a general education context, the word *technology* is often used as short form for computers and their related hardware and software. While computers are certainly part of technology, they are far from all of technology. For use in this chapter, the idea that technology is a "body of knowledge and actions" is perhaps most important. So, while technology includes hardware and materials, the organizational systems humankind develops to derive the benefit from technology is perhaps even more important. Saws and hammers, like computers, are artifacts of technology, as is the supply and distribution system that gets tools, materials, plans, and people all to the right place at the right time to produce a good or service.

Wright and Lauda then describe what technology education is. "Technology education is an educational program that assists people develop an understanding and competence in designing, producing and using technology products and systems and in assessing the appropriateness of technological actions" (1993). They are talking about an educational program. Wright and Lauda state that it is "to assist people." Since most education programs are intended to assist people, it is helpful to look at two specifics of technology education. The first, and more obvious part is to assist people in gaining an understanding of what technology is, how it is used, and how to use it. Upon completing a study of some aspect of technology, students should be able to describe and explain it. They must also be able to apply what they have learned in a material way. The second part involves "assessing appropriateness." Here students should to be able to stand back from the technology they do or observe and ask questions such as, Is that good for me? Is it good for other people? Is it good for the environment? This part is the ethical dimension of technology.

AN OVERVIEW OF LANGUAGE ARTS AND LITERACY

The language arts refer most frequently to the processes of reading, writing, speaking, and listening. Some curricula also refer to viewing as one of the language arts. In many books the four processes are addressed separately, but virtually all research shows that they are closely entwined. Children have an innate ability to learn language. The language arts help develop this central language function, and all processes are integrated at the core of language learning. Just as children talk about what they read and what they view, they often talk before writing and also write on the basis of what they have read. The inter-relationship of the processes must be understood, so that resources for poetry, vocabulary development, creative writing, spelling, and drama are not viewed as discrete entities.

Literacy most often refers to two of the language arts, reading and writing. Today's school no longer advocates learning to read and write as if they are ends in themselves but rather stress reading and writing as important processes in communicating meaning. Thus children are involved in authentic experiences of reading real books and writing their own stories. Early in the schooling process, children become aware of a wide range of written forms and make choices about what to read and write. They develop awareness that an author is trying to communicate to them and that the meaning they construct of another's writing is greatly intertwined with their own experiences. Conversely they write to explicate their own stories and soon develop a sense of audience and communicative purpose.

A critical component of this approach is placing reading and writing at the center of the school day. It is a very profound truth that children learn to read by reading and write by writing, and continuous opportunities to apply these processes to diverse topics fosters children's literacy development.

The mechanics of reading and writing are also placed in a different perspective. Analytic skills, like phonics and syllabification, and written conventions, such as punctuation and spelling, are viewed as means toward being understood. Consequently these topics are taught in applied ways not as lessons disembodied from their use. For example, the use of quotation marks will be discussed in writing about others, because these marks indicate the exact words of a speaker. We will then observe it in the children's writing when they want to convey the actual words of a character. In this way the link between the form and its application is established from the outset so the conventions and their application are learned in tandem.

In the complete language arts program, talk—the joining of listening and speaking—is also given significant attention. Research shows that oral communication is critical to life success and social development. Of equal importance in the development of literacy is the realization that a child's talk in the form of brainstorming before writing, in conferences about reading and writing, and in sharing one's own writing by reading aloud all complement the growth of literacy.

As the decade of the 1990s closes, the complementarity of the separate language arts becomes increasingly established. Using speaking and writing as bridges to reading is evident throughout the professional literature. Similarly traditional programs that have approached the language arts as separate disciplines give more attention to the transfer of skills across subject areas (Hansen, 1987)

The critical factor is that language requires content—experiences, ideas and questions—that require language for their expression. Technology is an ideal content. Experiences that are novel, thought-provoking, and cognitively engaging provide excellent content for language use. Activities that combine both manipulative experience and language use are especially powerful.

INTEGRATING TECHNOLOGY EDUCATION AND LANGUAGE ARTS

Everyone knows that technology or "shop" programs are commonly found in junior and senior high schools, but what does technology education have to do with the language arts curriculum in the elementary grades? The answer is both simple and profound—children fuse experience and language in the process of cognitive development. When children are considering both the material and ethical dimensions of technology they use and expand their language in the service of this exploration. Conversely, expanding experience into the realm of technology provides new ideas, structures, and functions in which to extend previously developed language. Thus technology education and language learning can be complementary in the educational development of children. When educators talk of integration, they usually mean merging subjects that could be taught separately. This case involves integrating, talking, writing, and reading within the language arts and the integrating all of language arts with technology.

A unit on communication would be a prime example of this fusion. The technology of communication is becoming more and more a part of children's daily lives. They are often the family experts in operating television sets, video recorders, tape recorders and CD players. Computers are an integral part of their experience, and computing networks are providing them with opportunities to access all corners of the world. Children learn terms associated with communication, and these terms become metaphors for other aspects of life. "Don't give me static" is a long-standing metaphor. The need to "down-load" and "interface with" new information is more recent. The distinction between individual and mass communication is becoming less distinct, as individuals become able to customize their access to mass media by blocking some channels and subscribing to others, for example. They can also communicate to specific groups of people through fax, computer networks, and copying machines.

There is a dynamic interaction between the content of the communication and means of the communication—the interaction between language arts and technology. Many of the neologisms of the language (Yellin & Blake, 1994) and new conventions of grammar and punctuation have their origin in technology. Students familiar with a range of websites have attached meaning to the punctuation //. We commonly hear the phrase "I'll e-mail it to you," the development of a new verb from the technical short form for electronic mail.

Another commonality between language arts education and ESTE is the emphasis on "real" experiences. This emphasis is not to decrease imagination or creativity but to emphasize the purposefulness and validity of the experience. In language arts teachers must encourage children to read "real" texts for valid purposes and write "real" text for exploration and communication.

The term "authentic," which is frequently applied to reading and writing activities, is of equal importance in ESTE (Scobey, 1968). The activity must reflect the "real" uses of materials and processes. Similarly, "toy" tools, which may be dysfunctional and often dangerous, must be supplanted by "real" tools and "real" materials suitable for child use. Another issue that is broadly discussed in technology education literature is the degree of "realness" necessary for good learning. Although no one would expect to bring real "rocket boosters" into a classroom, most technology educators reject the idea of using cardboard rolls as substitutes. The activities involving technology must be planned so the materials help children develop accurate concepts of the actual materials involved.

One more advantage of pairing language arts education and ESTE is its potential for inclusion of all children, which responds to the criticism that schools gender-stream our children—that boys "do" things and girls "talk about" things. The fusion of ESTE and language arts education provides more balanced educational opportunities for both boys and girls. In addition, children with strong preferences for either language arts or technology are more willing to broaden their experiences when their preferred activity is included. Similarly the use of concrete materials paired with language may meet the needs of children in multi-ability classrooms. For some children the concrete hands-on experience is more critical to their learning. These children may be more willing to participate in group discussions, group charts, storytelling and writing because the hands-on experience was more interesting and more comprehensible.

PLANNING AN INTEGRATED LANGUAGE ARTS TECHNOLOGY ACTIVITY

The following section details the planning steps for an integrated language arts-ESTE activity. An essential component in allowing both technology activities and language development to prosper in unison and interaction is creating the classroom climate that allows for talking, exploring possibilities, checking with an adult for meaning and discussing the experience with other children. Critical to this, however, is selecting an enticing, exciting project upon which language can focus.

Step 1. Select an Activity

An ESTE activity can be either a process in which the focus is upon the activity but no lasting product results or a process in which a final product serves as an incentive for completion. Of course, the activity needs to be one that interests children. Often the necessary interest can be generated through careful motivating and interest-building activities on the part of the teacher.

When selecting an activity the first consideration should be the abilities of the children. Further considerations include: adequate space, proper facilities and the appropriate tools and materials to carry out the activity. For the activity to be successful, it must be one with which the teacher will be comfortable. If this approach to teaching is new, the teacher should choose a relatively simple activity so that success is certain. (The instructions at the end of this chapter describes a simple activity that produces a usable product, an adhesive-bound pad of paper.)

Step 2. Conduct the Activity

There are many sources of activities, but, often when a published suggestion is used, the teacher must expect that the activity will not work exactly as described. Equipment, facilities and materials may differ from those used in the published source. Differences in the range of ability and background experience of the children or the teacher may lead to the activity not being the same as that described in the source. It is also possible that some critical part of the described activity has been omitted from the description. Sometimes teachers select activities that have instructions prepared for adults. These instructions assume underlying skills that the children may not have. This assumption can be seen in cooking recipes where the instructions are complete and satisfactory, if the reader already knows how to do each of the steps. Whether the activity is taken from a published source or is the teacher's own idea, the single best way to identify and solve problems is for teachers to do the activity themselves before the children become involved.

Step 3. Modify the Activity as Necessary

"Piloting" the activity allows teachers to modify the activity to suit the circumstances in which their students will use it. Teaching objectives may require a modification but so may other things, such as the availability of materials, tools, facilities, and funds. The teacher should be careful in deciding on changes. If there is a downgrading of materials, tools, or facilities. The teacher may need to answer the following questions: Will the activity still be satisfactory? Will the product still be worthwhile? Will it still have a use and attraction for children? Conversely, upgrading materials, facilities, or tools could result in a far superior activity, one which has more lasting pedagogical or other value for the children.

When the teacher is through with this stage, he or she should have an attractive, useful activity that can be completed successfully by the children in her/his class with the materials, tools, and facilities available. This is one of the critical steps in planning for the children's success.

Step 4. Identify Materials

Most often technology activities require materials of some kind. These materials may be as simple and as common to schools as paper and glue. However, other materials not typically thought of as "school materials" may also be required. An example of such a material is sheet aluminum. If it is needed, will beverage containers do or must the local builder's supply be scouted for availability of sheet aluminum? Careful thought must be given to materials; the major materials are often obvious but need careful description and preparation in order to have material that children can easily use. Items that are not immediately obvious may be essential to the success of an activity. For example, in developing the plan for a note pad, is there a suitable material available to make the backing? Must it be purchased or can something that is available be adapted? To define these needs it will be necessary to compile a "Materials List." When compiling the list, it is also useful to indicate likely sources for the materials. Staff at a craft store or a building supply center can help supply information on questions, such as the right glue to use with specific materials.

Having completed and revised the activity and compiled a materials list, the teacher should list the other requisites for the activity. A "Tool List" should be developed to show the actual tools used in the activity. Then the teacher should determine what type of space and facilities are required and how many students will participate at one time.

Once these items are considered, the teacher should consider the number of tools and amount of materials for the number of children. If all children in a class do the same activity at the same time, more tools will be needed than if children are organized on the basis of activity centers. The quantity of material required will depend on the number of children doing the activity. Sometimes only one of a particular tool (e.g., an oven, a teacher-operated drill or a roll of newsprint) may be required regardless of the number of children taking part in the activity. Other items may be required in larger numbers depending on the instructional organization. For example, sometimes two or three children can share a hammer and saw; each child needs his or her own nails, or a container of glue may serve one table of children.

Step 5. Analyze the Production Steps

Having developed a "Materials List" and a "Tool List," the teacher should reflect on the processes implemented in piloting the activity. A careful analysis of the production as it will be carried out by the children should be conducted to understand the process from beginning to end; each step that each child will take; and the space, skills, and material necessary for each step to be successful. To gain this understanding the teacher should consider the following questions: Will the whole class be involved at one time? Or will small groups within the class do the activity sequentially over several days or weeks? Does the furniture in the classroom or activity room have to be specially arranged for this activity? Are any special items of furniture required? Does the teacher have to make or obtain any special facilitating items?

Usually an activity can be done in the regular classroom. If only a few children are to work on the activity at one time, a small area with a suitable table or bench will suffice. When an activity is to involve the whole class at one time the use of a separate activity room is very convenient although not strictly necessary. Each of the activity's operations and the sequence in which they must be done should be analyzed.

Using this analysis, the teacher should organize the workspace so that the flow of materials and the necessary movement of children during the activity can be accommodated. Children should be in "planned space" throughout the process. The teacher may want to consider the following questions: Where will children begin the activity? Where will you assemble things that should not be disturbed, such as newly glued or painted items? Are jobs that involve some mess located where furniture, flooring and so forth will not be damaged? Can messy activities be near a sink? Where will completed or semi-completed products be kept until they are ready for further use? Where will you need to focus a great deal of your attention? Do you need other adults or older children to help with certain stages of the process?

Once space has been identified, the teacher needs to consider the placement of tools and materials. Safety is of primary importance in this part of the planning. Questions to consider include: Where specifically in the work area will each kind of tool be used and where will it be kept when not in use? Which tools require supervision by an adult? Which tools need two children working together to manage the coordination?

Materials must also be included in the plan. Where specifically in the space will each material be used? Where will materials be stored, before and after use? Materials must also be considered in planning the space. Most activities that produce products also produce waste. How will the waste be gathered and where will it be stored? Do the materials or the waste have potential for being dangerous to children or pose a fire safety hazard or other problem that must be planned for as the production steps are analyzed? Are there any children who are unlikely to follow safety instructions?

Step 6. Plan Language Arts Components

A novel activity has inherent value for language development. Doing something useful with a reasonable degree of independence is in itself a significant contribution to language growth. Most children gain the most from the language experience if they talk to others as they are involved in the activity. An adult or an older child who can model new language patterns can be especially valuable for some children.

Expanding Language Functions Most enticing activities provide opportunities for collaborative and exploratory talk. These moments of growth typically occur when children communicate their ideas to others, searching for descriptors that capture the meaning of the experience. This growth is achieved by selecting a "real" activity and then accomplishing it—involving a range of language functions in the service of the completion of the activity. At the end of the activity, children may wish to write about the experience using a narrative style. Others might wish to simulate job descriptions, giving instructions for others. A natural activity would have the children compile an instruction book for other children or other classes to complete the activity. In many activities, materials must be purchased, information gathered, permissions requested, public relations materials distributed, and charts and diagrams made—all opportunities for children to collaborate in writing, talking and drawing their ideas. The children can use the technology of books, catalogs, telephone, the postal service and e-mail in obtaining or sharing information that arises naturally in a "real" activity.

Capitalizing on Teachable Moments In naturally occurring language some of the most teachable moments are those that arise spontaneously—questions about how to proceed, ideas on how to improve the activity, dialogue between participants—and provide opportunities to expand understandings. Because children are natural language learners, they assimilate important aspects of their environment and work at finding words to describe what they have experienced.

Fostering Vocabulary and Language Development For many children a new activity produces vocabulary growth and descriptive language use. Learning language from experience can be fostered in a range of ways. For example, some children like to see the word for the new material they are using. Signs that show where materials and tools are to be kept help children become familiar with these words. Talking about sensory impressions—textures, smells, etc.—is contextually supported.

Any venture into a technology activity also creates awareness that some people do things like it for their work—that there are areas of interest like book binding, caring for and restoring old books, or binding periodicals for libraries. Visiting some of these industries, reading about the history and importance of book binding, and the significance of the broad availability of books to the general public are all topics that could arise from children's interaction with this technology activity.

Many sound poems, stories and songs fit into the technology context. Teachers should allow children to make some leaps of fantasy as products unfold. Similarly, they should provide opportunities to encourage the appropriate technical vocabulary—tool names, names for processes, and names of products. The students should be encouraged to consider the "life" of something. Nails do not just occur in nature. Where could this nail begin, and how did it get here where it can be used?

Step 7. Prepare the Activity

There are two main components to preparation at this stage. The simpler component is a matter of looking after details, such as preparing lists of tools and materials that will be required, obtaining them, and arranging the space in which they will be used. In setting out both tools and materials, some checking needs to be done to be sure that the materials, are indeed the right materials and that the tools are in usable condition.

The more complex component is to think through very carefully all of the things children will have to do and what instruction they will need in order to do those things. Which processes will have to be demonstrated? Which processes are complex enough that the children doing them will need to practice before they can perform the tasks to a satisfactory level? When this detailed readiness planning is complete, it will be time to plan the activity with the children.

Step 8. Plan the Process with Children

Before the children begin an activity, mutual planning is important. The new activity should be introduced in the way that is most familiar to the children and teacher. All of the things that have to be done and which children will do each of these things should be discussed. Just as educators advocate "authentic" activities, they also recommend "authentic planning." Some activities can be planned by the children using a wide range of options, and their ideas can be followed. Others have very few options. In planning with children, teachers should be truthful when describing the options in restricted cases so that children can understand the reasons for constraints and select from the viable alternatives.

Teachers should lead the children through the process of planning space, tools and materials, so the children will also go through the same kinds of analysis as the teachers have done. This analysis is a critically important stage of the activity—the children need to have a clear view of the whole activity. Understanding why things are being done as they are and how the whole process should go forward builds the bases for planning subsequent activities.

Step 9. Demonstrate Results

Some processes will be familiar to the children; others will need to be demonstrated. Throughout the demonstration, the teacher needs to be cognizant that some steps can be performed in a range of individual ways. Children should be allowed some freedom to express their own preferences at these points. Other processes must be performed exactly as shown either for safety reasons or to assure the success of the product. Teachers need to identify these steps clearly to the children during demonstration. If necessary, they need to provide direct instruction on a specific skill. For example, children may decorate their product in a wide range of ways as they choose. However, if they wish to glue two things together, they will have to clamp them or weight them to be sure the glue binds both surfaces.

This step is also a good opportunity for the teacher to facilitate language use by putting key words on the chalkboard, referring to their notes as needed, and using the vocabulary of the activity.

Step 10. Assist and Monitor

The teacher should move about the area and observe the children's progress, which will provide an ideal opportunity for evaluation through observation. The teacher may choose to use a checklist based on the lesson objectives established during the planning phase or record anecdotal notes about salient performance by the individual children. This step, although critical to the project's success, is the same as providing support to children during any school activity. Finding the balance between allowing independent problem solving but supporting children's growth is as critical now as in other aspects of teaching and learning. If the materials and processes have any hazardous components, they should have priority for the teacher's attention.

Step 11. Clean Up

Cleaning the work space and returning materials carefully is actually part of the learning involved in project work. Although the procedures were outlined during the planning stage, most children need teacher support to complete this phase. The teacher should determine in advance whether any special handling will be necessary in disposing of materials. For example, rags that have paint thinner on them can ignite if not disposed of correctly.

Step 12. Facilitate Closure and Evaluation

Closure in an integrated language arts and technology lesson parallels that of other classroom activities. It is the opportunity to review what has happened, synthesize the activity and incorporate personal experience. As a result, the children may be able to integrate the concepts and experiences, remembering the activity and the concepts related to success. This step is also the time to focus again on new concepts and vocabulary so that the new words and ideas will become part of the children's lasting language repertoire. It is necessary to keep this closing discussion energetic and brief. Gathering ideas on how to vary this activity next time or how to use the product provide teachers with positive bridging for later technology-language activities.

Follow-up for the Teacher

Literature on teacher development consistently shows that professional development is most powerful when directed by the individual teacher. In this case, the teacher will need to develop his or her own skills at planning and orchestrating technology activities, as well as integrating ESTE and language arts. This development has both theoretical and applied components.

At the close of each activity the teacher will need to do an individual evaluation of the processes and student responses. To facilitate later activities, the teacher should keep a file that includes the materials list, tools list, steps in the process and reflections after completion. Over time an individual teacher or team of teachers can develop a repertoire of activities that are suitable for children, improving each activity or discovering new ways to extend understandings with each group of children.

As experience develops, teachers begin to think more creatively. Often teachers have experienced narrowly defined craft activities in their own schooling and fail to consider the learning potential of integrating authentic ESTE with other curriculum areas.

INTEGRATION OF LANGUAGE ARTS AND TECHNOLOGY EDUCATION REVISITED

The integration of ESTE and language arts education through carefully planned experiences provides opportunities for cognitive and linguistic growth. When the activity is engaging, the complementarity of language arts and ESTE allows effective growth and development for children. Children remember what they do. They understand cause and effect when they experience the results of an activity. The concepts that develop as part of these activities become more salient, more transferable and more memorable when they are attached to language. Harnessing the power of manipulation of concrete materials to the power of language for comprehension and abstraction promises significant learning for children.

Constructing a Notepad: An application of procedures

In this section the production of a simple notepad will illustrate the procedures detailed in the preceding chapter. This activity is only one of a nearly infinite number of technology activities which may be employed in elementary schools. Many of these provide a meaningful milieu in which language is developed. The teacher who is a novice to this type of activity can begin with something this simple to assure success. More complex activities can be undertaken as the teacher extends his or her competence or in collaboration with more skilled technicians.

THE BASIC NOTEPAD

Step 1. Select an Activity

The notepad was selected for several reasons. First, the activity produces a product potentially connected to language. Second, most children can use a notepad; it is a product children recognize and may have used. Third, technology activities are new to the class and the notepad is a simple introduction to the process. Each child should be able to feel successful when the product is complete.

Step 2. Do the Activity Yourself

Since this activity was one for which no directions were readily available, a tentative design decision was made and a tentative procedure developed to pilot the activity. The decision was to make a small notepad, one for which the paper could be easily and economically cut from an 8″ by 11″ standard size sheet of paper. If the notepads are 4″ by 5″, each standard sheet yields four notepad sheets.

An ordinary office paper cutter was used to cut the paper. Cover stock for the notepad was cut to notepad size from a file folder. A workbench vise (one of the widely available home workshop models in which the whole bench top forms the vise jaws) was used to clamp the paper and cover stock; then padding compound was applied. The next day a second coat of padding compound was added. The third day when the vise was released a usable notepad had been made.

Step 3. Modify the Project as Necessary

Reflections on the process employed in the pilot described above brought about two procedural changes that were necessary for children to participate in the activity.

1. **Cutting the paper.** It is difficult to make consistent, accurate cuts with the kind of paper cutter typically found in schools, so some improvement in the procedure was needed to improve the process. The paper stack can be marked on the edges where cuts will be made. These marks will help children in making the

necessary cuts fairly accurately as they cut a few sheets at a time. Plan for proper supervision of this activity or devise procedures and rules to ensure that errant fingers don't find their way under the cutter. If two cutters are available, it would be worthwhile to clamp a fence on each (see figure 1). One fence would determine the vertical dimension of the paper, the other would determine the horizontal dimension. After each cut is made the paper should be stacked so that the original edges are kept together. This process will make the paper easier to pad later (see figure 2).

2. **Clamping the paper.** The vise proved a little awkward to use for holding the paper; a simple padding press can be made that will make this an easier process (see figure 3). If the padding press is made with a fence it is even easier to use.

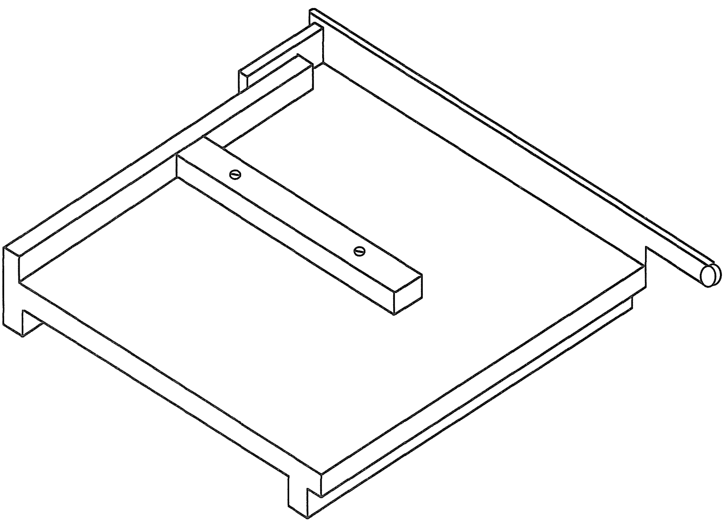

Figure 1 *Papercutter with Fence.*
This figure shows a paper trimmer with a "fence" attached with screws to the working surface of the paper trimmer. The fence makes it possible to cut many sheets of paper on successive cuts consistently to the same size. Suggested material: 1 x 2 wood [actual wood size will be about ¾" x ½"] of sufficient length and two #10 flat head wood screws 1½" long.

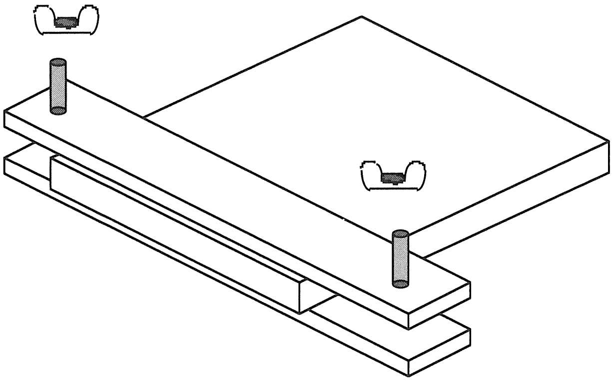

Figure 2 *Simple Padding Press.*
This is a very simple padding press. Suggested material: two pieces of 1 x 2 wood 12 inches long, two 5/16 - 18 UNC bolts 2½" long and two 5/16 - 18 UNC wing nuts.

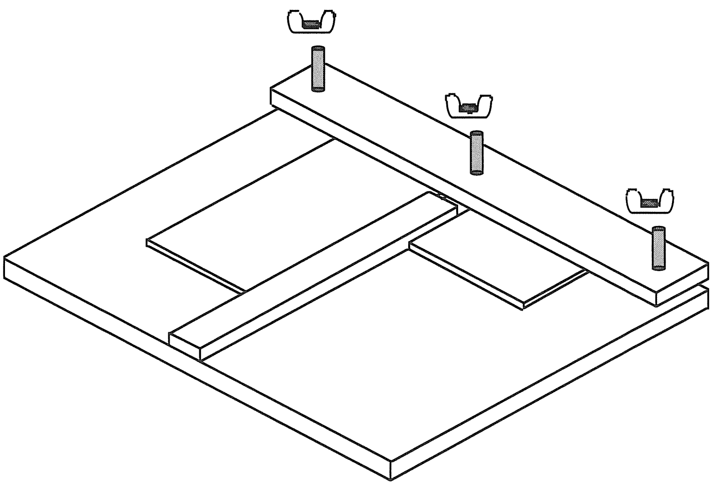

Figure 3 *Better Padding Press.*
Showing two different sizes of paper ready for padding. Suggested materials: base, 1 piece ½" x 12" x 20" plywood; clamp bar, 1 piece 1 x 2 wood 20" long; fence, 1 piece 1 x 2 wood 10½" long; bolts, 3 bolts 5/16 - 18 UNC 2½" long; wing nuts, 3 nuts 5/16 - 18 UNC. The fence should be permanently fastened to the base with glue; the press will be easier to use if the bolts are also fastened permanently to the base.

Step 4. Identify Materials

When defining materials, define them broadly so that everything consumed, whether part of the finished product or not, is included. The materials for this activity are quite simple: paper, cover stock (tag board is better but a file folder is acceptable) and adhesive. For this project, it is assumed that file folders will be used as cover stock and that each notepad will have a piece of this material on top and bottom although it would also be satisfactory to have the cover stock only on the bottom of each notepad.

The adhesive used for this type of project is padding compound. It comes in quart or liter containers, usually plastic jars and is available from graphics industry suppliers. Select a latex-based compound for ease of cleaning up.

Because padding compound is a somewhat messy material, thought has to be given on how to confine the mess and how to clean up afterward. Newspapers to protect the table from the adhesive, and paint smocks for the children to wear so they don't get padding compound on their clothing will also be useful. A large roll of paper towel should be available for clean up. The brush can be kept from drying out between uses by storing it in a small plastic bag.

When making a tool list, define "tool" very broadly so everything will be listed. For this project, paper cutters with a fence for improved accuracy, padding presses for holding the paper when padding compound is being applied and until it dries, brushes to apply padding compound, small jars with lids to hold the compound and a knife for separating the completed pads are needed. The small jars, preferably unbreakable, are to hold padding compound while students are using it. Decanting the compound into smaller containers avoids the possibility of a major spill. Almost any small, sharp knife will do for separating the completed pads.

Thus the tool and materials lists for 32 children will be as follows:

Material List

- Paper: 225 sheets of white typing/copier paper (includes extra paper to allow for demonstrating the process and errors).
- Cover stock: 5 file folders to be cut to 4″ x 5″.

- Padding compound: one quart/liter (only a small amount will be used).
- Plastic bags: 1 package of sandwich bags (only a few will be needed).
- Newspapers: enough to cover table.
- Paper towel: 1 large roll.
- Paint smocks for children working with padding compound.

Tool List

- Paper cutters: 2 with fences.
- Padding press.
- Small container for padding compound (baby food jar).
- Brush: 1 inch, stiff bristles for applying padding compound.
- Knife: small and sharp (an 'Exacto Knife' would work well).

Step 5. Analyze the Production Steps

The next step requires planning the organization of the activity. For this project, it is assumed that a notepad will be produced for each child and that the children will work on the notepads in groups of about eight. These groups will involve a division of labor and specialization in the tasks to be performed. No child will do all of the operations to be performed in producing the notepad, but each child will specialize in a smaller group of tasks, repeating them a number of times. Cooperation will be a key component of the notepad activity.

A possible spatial arrangement is to have, in one part of the room, three work areas with separate tasks performed at tables in each area. One table would be designated for cutting paper and cover stock, another table for assembly of paper and cover stock pieces into pads, and the third table for applying the padding compound. This is only a suggested arrangement; it would also be possible to do the whole activity at one larger table or counter with either fewer or more children.

The paper cutters will be placed beside one another so that paper may be passed from one cutter to the next. After the second cutting, the paper and cover stock pieces are passed to the second table so that the pads can be assembled like a sandwich with tag board or file folder on the outside and paper in the middle. At this table it will be important to keep the factory–cut edges correctly aligned and to make sure that the correct number of sheets of paper are included in each pad. As each pad is assembled, it can be passed to the table where padding compound is applied. Children working at the padding table will check each pad to see that it is correctly assembled and then place each pad in the padding press. When all of the pads have been assembled and placed in the padding press, the press can be tightened or clamped and padding compound applied.

Procedure list.

After analyzing the production steps and the skills of the children, the following procedure list was developed for this activity.

Preliminary.

- Arrange tables in work area.
- Arrange paper cutters on cutting table and cover table used for padding with newspaper.

Cutting Area.

- Count out pieces of cover stock (if file folder is used the teacher should precut it to 8″ by 11″.
- Cut cover stock to 8″ x 5″ one sheet at a time.
- Cut cover stock to 5″ x 4″ one sheet at a time.
- Pass cover stock to the assembly area where it should be stacked, keeping the original edges together.
- Precount or estimate the amount of paper and mark the edges of the paper stack. Each edge should be marked twice with a felt tip pen or similar marker, one mark at about the middle of what will be each edge after cutting.
- Place the paper near the first paper cutter.
  - Count five pieces of paper and cut to 8″ x 5″

- Pass two five sheet stacks of paper to second paper cutter.
- Cut paper to 5″ x 4″, five sheets at a time.
- Pass the paper to the assembly area.

Assembly Area.

- Place four cover stock pieces on the table in front of assembly workers.
- As paper is received from the cutting area, place it on the cover stock pieces. Each set of five original-size sheets should now make four pad-size sets of five sheets. The marks put on the paper edges before cutting should align in each of the four separate pads. Each pad should have edges marked on one long side and one short side.
- Repeat this process four more times until each pad has twenty five sheets.
- Place cover stock sheets on top of each pad.
- Pass assembled pads, separately, to the padding area.
- Repeat the above steps until all pads have been assembled.

Padding Area.

- Check each pad as it is received. Do the edge marks line up? Does each pad have the right number of sheets? Are they all the same thickness?
- Jog each pad on the table top so that the marked edge on which the padding compound is to be applied is smooth. (The other marked edge should also be smooth).
- Put the checked and jogged paper carefully aside and begin to make four stacks.
- Repeat the first two steps above and continue building the four stacks of pads with the paper edge markings aligned until all the pads are assembled. (If eight children are making pads, there should be two pads in each pile. In making pads this way it will

be best to always make a number that is a multiple of the number of pieces cut from each original sheet of paper.)

- Make two sets of pads by turning one set over and placing it on another set. Do this so the marked edges are kept together.
- Jog each set of pads again so the marked edges are aligned and smooth.
- Place one set of pads in the padding press against the fence with about ⅛″ (3 mm) of a marked edge extending beyond the padding press base.
- Place the other set of pads in the padding press against the other side of the fence in the same way.
- Fasten down the clamp bar (top) of the padding press, taking care not to disturb the stacks of pads

Apply padding compound.

- Set padding press with pads aside to dry. The pads will stay together better if a second coat of compound is applied the next day. It is not necessary to leave the pads in the padding press once the first coat of compound is dry.

Cleanup.

- Pick up paper scraps.
- Dispose of newspapers.
- Clean brush.
- Rearrange furniture.

Step 6. Plan Language Arts Components

Producing a pad of paper is a very adaptable task—notepapers, colored papers, writing pages with colored paper covers, or collections of poetry, stories, or journal pages can all be created. The opportunities to create special pages for writing personal ideas or books to share immediately come to mind. Making personal or class collections of writing, poetry, art work and journals become possible.

While making the pad of paper children learn the names for new items, such as *padding press* and *adhesive*. The most interesting experiments with words occur as children derive verbs or adjectives from the new names they have learned. Similarly, as they try to describe to each other the smell and consistency of the adhesive, the pressure of the padding press, the challenge of holding pages still and the satisfaction of the final product, they explore the use of familiar words in a new context. For example, in the paper tablet project, the term "clamp" may be new to the students. Clamp is one of the words of English that serves as both a noun and a verb. Not all words function this way, and a novice learner will attempt these variations and follow the model of the senior speaker. Actual experience with this word provides the basis of the understanding for idiomatic and metaphoric expressions such as "really clamp down on that."

Writing key new words like "adhesive" and "clamp" on the chalkboard helps some children use the words later. A few also like to have the sequence of steps written as they feel more secure attempting a new activity without relying on memory for this information. This step is an example of functional reading—reading for a purpose.

To illustrate that technology education provides worthwhile experiences and also a product for language arts, this notepad will be used in a language activity about "wonderful words." The children's attention was focused on the potential use of words by being asked to pay special attention to the richness, texture, and imagery of words—that were diverse examples pulled from poetry or Dr. Seuss. As an ongoing activity, children are collecting "wonderful words" that produce pictures and sensations in their own minds. The next step is to use the pages of the notepaper to write "wonderful words," one word on each page. A large, spreading word tree was then planned for the back bulletin board, which was filled with children's word choices—grouping them into branches the children defined. Definitions included happy words and scary words. In the process of developing these trees, the teacher also added some words from the notepad activity to encourage application of language across experiences.

Step 7. Prepare the Activity

Considering the developmental level of the children, the following questions were considered to prepare the notebook activity: Will they need adult help to get a smooth covering of glue or to make the clamp fit over the stack of paper? The following steps were performed by the teacher prior to the activity to help anticipate and prepare the activity:

- Teacher preparation for the notepad activity.
- Set up tables, put down newspapers.
- Count paper into piles of 25.
- Pour padding compound into small jars with lids.
- Put cutters, brushes and other materials in place as planned.

Step 8. Plan Process With Children

The children were told that together they were each going to make a notepad. Since this was the first activity of this type for the group, it was stressed that they needed to plan together to make the activity work smoothly and have the product turn out well. They were also told that some rules were just to help get things done and some were for safety but some rules are so important that things won't work at all unless rules were followed and the procedures were done right. The most important steps are to cut the paper, put the paper in the padding press, and then put adhesive on one edge of the stack of paper. Before the children start making the notepads, the class needs to plan how they are going to use the space by answering the following questions:

- How will we take care of these things?
- How do we keep adhesive from getting on children's clothes and the table and floor?
- If we need only one person per group putting on padding compound, who should take that role?
- Where careful checking needs to be done so that the pads turn out right who should do the checking?

- When we need two sets of hands to get something done, can people work in pairs?

Step 9. Demonstrate Results

- The teacher begins the demonstration by showing the finished product so the children understand what they are making.
- The teacher demonstrates counting out five sheets, making the edges even and placing the small stack on the paper cutter.
- The teacher emphasizes the place they can put their hands on the paper when bringing down the blade. The teacher also demonstrate safe use, points out safety rules and shows how the fence will help align the paper during the cutting.
- The teacher shows how each cut half must now be turned for the second cut.
- The teacher demonstrates stacking all the paper neatly; emphasizing the need for one especially even edge. The teacher also makes it clear that this requirement is critical and that people should help each other achieve this.
- The teacher places the cover stock on the top and bottom.
- The teacher places the paper in the padding press and tighten clamp bar.
- The teacher applies the padding compound carefully.
- The teacher puts the padding press aside on newspaper and let the padding compound dry.

Step 10. Assist and Monitor and Observe

- If this is the first use of this type of activity, the teacher should keep anecdotal notes throughout the project to evaluate the process, the materials, and the children's performance. The teacher must be careful to note ideas for improvement and modifications. In subsequent activities of this type, anecdotal records of each child's performance in relation to the lesson objectives should also be kept.

- The teacher should pay special attention to the paper cutter; having another adult or older child monitor this table if there is any possibility of a child misusing the cutter, or pre-cut the paper if there is a perceived danger here.
- The teacher watch that the application of padding compound is generous enough to actually hold the pages together.
- The teacher helps the children remember the steps necessary after their turn at the work table–closing up the padding compound, placing the brushes in plastic bags, respecting that others' finished products need to be handled carefully, especially while drying.

Step 11. Cleanup

- When children are just beginning these ESTE activities, it is important to develop understanding that cleaning up is an integral part of the process and needs to be efficiently and routinely performed as soon as the activity is completed.
- This is a good opportunity to teach about removing newspapers that have wet or fume-producing material. They should be removed from the building.
- It is also important to be careful not to disrupt the notepads as they dry.

Step 12. Facilitate Closure and Evaluation

The children should be guided to talk about what they experienced, what they believe they produced and how they might use their notepad. In view of the language arts activity to follow, this is a good opportunity to include new vocabulary words and include sensory impressions in the summary.

Ideas for other uses of this activity can be considered as well. Some children might want to know where to buy padding compound for use at home.

Teacher Evaluation

Finally, the teacher should consider both what went right and what could have been improved in the activity itself. Did the padding process work? Did children spend too much time moving from table to table rather than cutting and clamping?

The teacher must learn to observe the children's success with the procedures and also the language uses prompted by the activity. Was there anything inherently interesting about the prompted conversation? Were sensory impressions, personal views expressed during closure? Did children use key words or steps written on the board in completing the activity? Did the pages of "wonderful words" add to language development?

Notes should be kept for the next time this activity is used. A file of activities can be built up and procedures can be developed that maximize the children's success and the learning potential. The teacher should develop her/his own skills in facilitating the children's experiences with materials and language.

Suggestions for Expanding this Activity

This activity could be expanded or modified in a number of ways. A variety of paper—colors from fluorescent to plain white—could be used. Recycling paper from the school office that had been used on only one side would be an environmentally sensitive consideration. If used paper is utilized, the teacher could try to arrange it so that after cutting the factory cut edges are all together. This arrangement will make applying padding compound easier.

Note pads might also be developed that are in part preprinted. The class or each individual in the class could design their own custom note pad page. These designs would need to be preprinted either by using the copying machine or some other method. A preprinted message, such as "Message from Mike," or "From Sue's Work Bench," would need careful planning so that the printed sheets could be later cut to make notepads.

This activity could also be modified to produce a booklet of student work, either a class collection or the work of individual children. If the class has access to a computer and appropriate software the computer might be used to format and print student work and page layouts that could then be reproduced and bound using the basic notepad idea.

An Interdisciplinary Technology - Language Arts Unit

LESSON ON THE DESIGN PROCESS

Language arts concepts

Cognitive and linguistic growth, development of language and functional reading.

Technology education concepts

Process for product development and assembly-line production.

Objective:

Students will design a notepad that they can use in school or at home.

Materials:

- Paper: 225 sheets of white typing/copier paper.
- Cover stock: 5 file folders to be cut to 4″ x 5″.

- Padding compound: one quart/liter (only a small amount will be used).
- Plastic bags: 1 package of sandwich bags (only a few will be needed).
- Newspapers: enough to cover table.
- Paper towel: 1 large roll.
- Paint smocks for children working with padding compound.
- Paper cutters: 2 with fences.
- Padding press.
- Small container for padding compound (baby food jar).
- Brush: 1 inch, stiff bristles for applying padding compound.
- Knife: small and sharp (an 'Exacto Knife' would work well).

Procedure:

1. Arrange tables in work area.
2. Arrange paper cutters on cutting table and cover table used for padding with newspaper.
3. Count out pieces of cover stock (if file folder is used the teacher should precut it to 8″ by 11″).
4. Cut cover stock to 8″ x 5″ one sheet at a time.
5. Cut cover stock to 5″ x 4″ one sheet at a time.
6. Pass cover stock to the assembly area where it should be stacked, keeping the original edges together.
7. Precount or estimate the amount of paper and mark the edges of the paper stack. Each edge should be marked twice with a felt tip pen or similar marker, one mark at about the middle of what will be each edge after cutting.
8. Count five pieces of paper and cut to 8″ x 5″
9. Pass two five sheet stacks of paper to second paper cutter.
10. Cut paper to 5″ x 4″, five sheets at a time.

11. Pass the paper to the assembly area.
12. Check each pad as it is received. Do the edge marks line up? Does each pad have the right number of sheets? Are they all the same thickness?
13. Jog each pad on the table top so that the marked edge on which the padding compound is to be applied is smooth. (The other marked edge should also be smooth).
14. Put the checked and jogged paper carefully aside and begin to make four stacks.
15. Repeat the first two steps above and continue building the four stacks of pads with the paper edge markings aligned until all the pads are assembled.
16. Make two sets of pads by turning one set over and placing it on another set. Do this so the marked edges are kept together.
17. Jog each set of pads again so the marked edges are aligned and smooth.
18. Place one set of pads in the padding press against the fence with about ⅛″ (3 mm) of a marked edge extending beyond the padding press base.
19. Place the other set of pads in the padding press against the other side of the fence in the same way.
20. Fasten down the clamp bar (top) of the padding press, taking care not to disturb the stacks of pads
21. Set padding press with pads aside to dry. The pads will stay together better if a second coat of compound is applied the next day. It is not necessary to leave the pads in the padding press once the first coat of compound is dry.
22. Pick up paper scraps.
23. Dispose of newspapers.
24. Clean brush.
25. Rearrange furniture.

Evaluation:

Inspect the notepads to ensure that the edges line up, that each pad has the right number of sheets, and that they are all the same thickness? The teacher watch that the application of padding compound is generous enough to actually hold the pages together. Did the children remember the steps necessary after their turn at the work table, and did they respect other students' finished products by handling the products carefully, especially while drying? Did the students participate in cleaning up by closing the padding compound, place the brushes in plastic bags and rearranging the furniture? Did the children work well together as a group?

Language Arts Component

Students will identify some of the possible uses of their notepads. These uses include: note paper, writing pages for collections of poetry or stories or a journal for writing personal ideas. Have the children identify some of the names for new items, such as padding press and adhesive. (Writing key new words like "adhesive" and "clamp" on the chalkboard helps some children use the words later.) The teacher may also focus on how words are experimented with by deriving verbs or adjectives from the new names they have learned. By describing to each other the smell and consistency of the adhesive, the pressure of the padding press, the challenge of holding pages still and the satisfaction of the final product, the children focus on these words as well.

Technology Education Component

Have the students identify their success with the production process. The teacher should lead the children in a discussion on how the production process could be improved, whether the process produced notepad that turned out well and according to specifications, if the assembly line process worked smoothly. Have the students identify the most important step(s) in the process. The students should also discuss the necessity of the rules for safety and production procedures.

Possible follow-up lessons:

This activity could be expanded or modified by using colored or recycling paper from the school office. (If recycled paper is used, a discussion on products with environmentally sensitive production methods could follow.) Notepads might also be developed that are in part preprinted. The class or each individual in the class could design their own custom note pad page. These designs would need to be preprinted either by using a copying machine or computer. A preprinted message would need careful planning so that the printed sheets could be later cut to make notepads.

This activity could also be modified to produce a booklet of student work, either a class collection or the work of individual children. If the class has access to a computer and appropriate software the computer might be used to format and print student work and page layouts that could then be reproduced and bound using the basic notepad idea.

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Chapter 5 Technology and Children's Literature

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INTRODUCTION

During a recent open house at an elementary school in the Midwest, visitors noticed some very special arrangements in one of the second grade classrooms. The teacher had cordoned off the corner with low lying, solid looking mahogany shelves jammed with children's books of virtually every description. The floor was covered with a deep, comfortable carpet, a fitting addition since there were no desks or chairs in the room. After a moment's thought, visitors could readily summon images of the young children who regularly occupy this space. Perhaps one of those children is lying comfortably on the carpet, her legs bent at the knee and her feet waving amiably in the air as her eyes peruse the book spread out in front of her. Another sits with his back up against the wall underneath the window, a book open in his lap. Yet another stands before the shelf, finger crooked in the corner of his mouth, merely trying to decide. Each of their faces bears the wonderfully scrunched-up expression of a child in deep concentration.

One last feature of this scene is the stillness. This is not a corner where students *have* to do schoolwork; rather, this is a place where they are *allowed* to go, and relax, and *read*.

And who *wouldn't* want to visit this corner? One of the shelves holds what must be this week's hot topic: dinosaurs. On another shelf, a dizzying range of subject matter can be found, from *The Magic Schoolbus* and *Curious George* to more sober volumes that present academic fare—such as the solar system and the life of Benjamin Franklin—in a way that children will enjoy and understand.

Although we can certainly make it sound magical, we must understand that there is no sorcery here. Elementary teachers such as the one who teaches this class have set up such places in their rooms because they know that to encourage reading steers children toward a lifetime of learning. Entirely by itself, whether in the classroom or outside of it, children's literature guarantees enrichment in the lives of those who read it. Imagine, then, the limitless potential for enhanced learning if educators were to carefully set up a system in which children's literature were to become a regular ingredient in every school subject. The reverse should also be true: we import elements of these school subjects into the study of children's literature, and not just the obvious disciplines, such as language arts or social studies, but mathematics, science, and technology as well.

At first glance, children's literature as a component of any of those last three disciplines might appear incongruous. The contexts of children's literature, however, often include social, historic, geographical, technological, scientific and mathematical concepts that captivate children. "In recent years new emphasis has been placed on using children's literature in virtually all areas of the curriculum" (Lukens, 1995, p. xi).

A technology activity unit usually focuses on a particular discipline. Ilott and Ilott note in the previous chapter that significant learning happens when the teacher harnesses the "power of manipulation of concrete materials to the power of language for comprehension and abstraction" (p. 126).

There are children's books that deal solely with technology and can capture children's curiosity and imagination. Perhaps no book does that better than David McCaulay's *The Way Things Work* (1988). The book itself, and a version on CD ROM, can be found in virtually every school in this country, testifying to the seductive interest that technology holds for children when it is presented in terms and settings they understand.

Those teachers willing to connect children's literature to other subjects of study find that students suddenly have a much wider spectrum of experiences with which to associate their learning; thus, they retain the learning outcomes much, much longer.

LITERATURE-BASED TECHNOLOGY ACTIVITIES

Reading and activity go hand in hand for children. Most of us can identify with children's literature expert Jill May, who describes her intense childhood relationship with reading and playing:

> When I was a child, I was a continual reader and dreamer. I read about Pocahontas and then role-played her life, using the tall corn rows in our garden as her forest; I read about Robin Hood and his merry men and I became a part of his merry band, wandering the forest land behind my Wisconsin farm home; I heard of Dorothy's trip in a cyclone to a magical land and imagined I was Dorothy from *The Wizard of Oz*, spreading newspaper across the living-room and dining-room floors to make my yellow brick road. (May, 1995, p. 3).

Literature-based technology activities integrate real-world experiences in highly personal and content-rich settings. As children recognize and understand stories, characters, relationships and place settings, like Jill May, they construct their own representations, and they often do so in active ways.

"Teachers who know the children in their classes will recognize the diversity of learning styles this sort of active learning accommodate. (They plan those diverse activities that enhance children's delight in books, make them want to continue reading more and better books, and cause them to think both more widely and more specifically about what they have read" (Huck, Hepler & Hickman, 1993, p. 781).

As children share what they have read with each other, integrated technology activities provide an expressive outlet for newly formed ideas and concepts children construct for themselves. "Employing a variety of methods of sharing books will serve to encourage participation from more children" (Lickteig, 1975, p. 363).

Lickteig goes on to give examples of sharing books, including making illustrations from a book, dramatizing it, and creating a book jacket. "Shoebox dioramas can be created to display a scene from a favorite book" (1975, p. 363). Other simple examples the writers of this chapter have used with children include making an audio tape or a video tape of an advertisement for a book the children have recently read, or making scenery, costumes and props to dramatize a story.

The writers have also used puppetry in many ways with children. "Puppetry allows children to plan a dramatization, create dialog, and work for effective use of the voice" (Sutherland & Arbuthnot, 1986, p. 586).

"In *The Three Billy Goats Gruff* the only necessary addition to a bare puppet stage would be the bridge and a hill with green grass. The characters an easily be constructed as paper-bag puppets or hand puppets with papier mâché heads" (Sutherland & Arbuthnot, 1986, p. 587).

With older children, more complex puppetry can be used, but it may not be necessary. "Marionettes (puppets moved by strings from overhead) require a good deal of skill to handle but finger puppets, hand puppets, stick puppets, paper-bag puppets, balloon puppets, and adaptations of these are easy for preschool and elementary school children, and even for many disabled children, to make and handle" (Sutherland & Arbuthnot, 1986, p. 587).

THEMATIC ACTIVITIES

Gamberg, *et al.,* prescribe a theme approach to an integrated activity. They suggest that a theme approach is not simply combining several school subjects to focus on a topic of interest. And, "it must be of interest to the children" (Gamberg, *et al.*, 1988, p. 10).

The children's interest will usually focus on what they have read or on the associated activity rather than the theme that the teacher has developed. A theme should bring together all relevant information. "Topics for activities can be generated as students create webs based on a selected idea, concept, or theme. Webbing creates a framework for the integration of content areas and encourages students to use their own creativity, imagination, and interests to shape the curriculum" (Rothlein & Meinbach, 1991, p. 331).

"The topic should lend itself(to breaking down the walls between the school and society that prevent children from using the surrounding world as a laboratory for their studies" (Gamberg, *et al.*, 1988, p. 10). As an example of a topical theme that could result in the integration of technology activities, Gamberg, *et al.*, discuss a study of oceans that would include the technology of the fishing industry from catching to processing. (1988, pp. 10, 11).

There are few topics that cannot be related to children's literature. Cohn and Wendt emphasize that "(t)he use of trade books is a thread that runs throughout the lower school math curriculum" (1993, p. 59).

The interdisciplinary nature of literature is made clear in a thematic approach to curriculum. Rothlein and Meinbach note that "(a) thematic approach combines a variety of materials, activities, and content areas to teach a specific concept, idea, or theme, thus offering a multidisciplinary, as well as interdisciplinary, approach to learning. And literature, no matter what the genre, easily adapts to the process" (Rothlein & Meinbach, 1991, p. 330).

Perhaps some practical suggestions would be most useful at this point, so let's examine a few selected thematic units.

Rationale for the chosen technology activity units

The first thematic unit we describe is based on *The Cat in the Hat* by Theodore S. Geisel, known as Dr. Seuss. Anita Silvey, for eleven years editor of Hornbook magazine, says that "people(fought over whether Dr. Seuss was a genius or someone who undermined children's reading skills" (1995, p. x). Parravano suggests that "Geisel's greatest contribution to children's literature...came with the publication of *The Cat in the Hat* and its companions" (1995, p. 591). Lystad further notes that the book was "attuned to the interest of the child, calculated to entertain him royally. The child was lured into reading, into becoming an active participant in the learning process" (1980, p. 196).

As if to summarize the argument for using Dr. Seuss' children's literature as a paragon, Long interviewed Anita Silvey, who said, "If we're talking classic children's literature, it's Dr. Seuss. He was his own kind of genius and his canon has to be considered a part of *the* canon" (Long, 1995, p. 3).

We have selected relevant literature for activities in this chapter. Teachers are encouraged to consult references to children's literature to validate their choices. Silvey has edited a wonderful reference to children's literature that covers children and young adult books of the 20th Century, emphasizing books published since WWII (1995).

THEMATIC UNIT ONE—*THE CAT IN THE HAT*

The Cat in the Hat entails two children stuck inside the house on a rainy day. They are seated at the window lamenting their boredom—

Mother has stepped out for a while, so the children can't even look to her for entertainment—when in walks a very curious cat. The Cat, who wears a red and white striped stovepipe hat, announces that their boredom is over: he has many games to play and things for the children to do. Their pet goldfish tries to convince the children that letting The Cat in was a bad idea, but he insists on staying. Sure enough, the games that The Cat has to offer are destructive in nature. The Cat and his friends, named Thing One and Thing Two, end up leaving the house a disaster.

The children finally capture Thing One and Thing Two and order The Cat out of the house. He sadly leaves, but the children now have the mess to contend with and the goldfish has spotted Mother coming up the sidewalk. Moments before Mother walks through the door, however, The Cat returns, riding a machine that he steers through the house, cleaning up the mess he and his friends left behind. The story ends with an entertaining moral dilemma: Mother asks the children what they did all day, and the children ask the reader how he or she would answer the question.

Activity One—Science and Technology

The teacher could get the children laughing by asking them to describe the worst mess they've ever created. Perhaps the children could draw a picture that depicts either the mess or the making of it. Then, the teacher could guide the children through a process in which they illustrate their own Cat-in-the-Hat style riding machine designed to clean it up. Activity does not have to cease with conceptual drawings: Tinker Toys© or K'nex© materials allow children to quickly make concrete reality out of their imaginations. Although the machine would likely not be reality based, the teacher could still introduce concepts based on what the children want their machines to do. For instance, the teacher could generate a "How Things Work" unit, which would examine such ideas as how much power is necessary to enable a vacuum to pick up the various objects left behind in the children's mess. The teacher could then branch off into different directions: discussions of wind generation, velocity and direction could ensue, which could then segue into illustrations about how the wind affects such weather as that which kept the children in the story inside the house all day. The teacher could help the children discover the workings of household technology, such as microwave ovens, refrigerators, or even garbage disposals. Children would enjoy taking a more in-depth look at the things they use around the house every day.

Teachers of the physical and biological sciences could take note of the point in the story where The Cat attempts to balance numerous objects while standing on a ball. One of the objects he seizes is the fishbowl. Of course, The Cat promptly loses his balance and falls. The physical/biological science teacher could interpose at this point a brief discussion of gravity, detailing ways in which humans achieve balance in precarious situations. The teacher could compare balancing abilities between various species, comparing humans to the squirrel racing across the branch or electrical wire. An ESTE activity might involve balance in structures, again encouraging the children to assemble commercial construction kits to achieve precarious balance. Further, the teacher could point to how the pet goldfish lands in a teapot when The Cat loses his balance. A discussion could follow about the environment of a goldfish, and the various technologies brought to bear on owning and maintaining fish as pets. Many elementary school classrooms already have aquariums that the children enjoy and have responsibility for. Their reality creates more meaning in the story.

Bernice Hauser (1996) has also created a Cat in the Hat unit of study for elementary school science, technology and society. Her focus is on hats from around the world.

Activity Two—Health and Safety

Not to be overlooked would be a discussion relating to health and safety. After all, The Cat does burst in unannounced and uninvited. Physical Education teachers might introduce students to ways in which technology is used to prevent the presence of unwanted visitors. Ideas ranging from complex home security systems to portable personal alarms to using a speed dialing device on a telephone could be introduced to children to promote within them a feeling of control over their personal safety. They could assemble simple circuits with buzzers, bells and lights. They could create designs for playhouses that would create safe and secure environments for the occupants. There is mutual interest in such activities and literature in the classroom.

THEMATIC UNIT TWO—*THE FOOT BOOK*

The Foot Book is short and simple. The text consists of quick, sharp rhymes, accompanied by brightly colored illustrations of various Dr. Seuss-style creatures with an unquestionably wide variety of feet. *The Foot Book* shows the creatures performing a variety of activities, such as running up and down staircases, or balancing on a ball while juggling. While *The Cat in the Hat* may have covered balancing, *The Foot Book* offers just as broad a range of possibilities for activities.

Activity One—Biological Sciences

Teachers can instruct children to select their favorite animal, and then have them list various things that their chosen animals do with their feet. Obviously, most children will immediately cite running or walking. But the teacher can offer guidance here. For instance, students who choose certain species of monkey will find that monkeys can grip, climb and swing with their feet. Some animals use their feet while eating, and others use their feet to defend themselves. Others may examine the leaping abilities of kangaroos or jaguars. Still more imaginative students may choose reptiles, such as fish or snakes, or certain mammals, such as seals or whales, and cover how those animals get around without feet. In any case, the teacher can point out that much of what we know about animals was garnered with considerable help from technology. He or she can then refer to such technology, from devices that record animals in their natural habitats to the methods used to subdue animals so that they can be studied. These technologies can assist the students as they produce illustrations that detail and compare the foot structure of different species. The children can construct habitats for their animals in shoebox dioramas.

Activity Two—Manufacturing Technology

Current American culture is very health conscious. In schools that have an active track and field program, or in an Olympic year for schools that do not, students can examine the various technologies used by doctors to study the human foot and to treat health problems the affect the feet.

The age of the plain old tennis shoe is long gone. Teachers can direct students to perhaps make a collage depicting different kinds of situations in which people wear sneakers, from athletes in the field, to Wall Street workers on their way either to and from work, to people who walk in shopping malls for health reasons. The class could host guest speakers from shoe companies, shoe stores, or shoe repair shops who could describe the differences between various products, materials and technologies of construction. Afterwards, the teacher could guide the students through an activity in which they brainstorm through the things they do in a day, and then design their own appropriate shoes or sneakers. Depending on the grade level (with younger students being more fanciful in their solutions) the students can use computer programs to aid them in design, and then they could construct a plan for the manufacture of their shoes. Teachers can work in such angles as the cost of appropriating materials, using technology to minimize the time spent on labor, and even the use of technology to market and advertise their product. To come full circle, the students could then design footwear appropriate for the characters in *The Foot Book.*

THEMATIC UNIT THREE—*STAR TREK*

Currently in its fourth incarnation, *Star Trek* has enthralled two generations for over thirty years. The original television series has expanded into movies, action figures, and a diverse spectrum of short stories and novels. Since children's literature is the focus here, we will examine ways in which teachers of elementary students in the higher grades could arrange a formidable variety of thematic units around either the short stories or the novels.

Activity One—Family and Consumer Science

Star Trek fans have always been fascinated by space travel, weaponry, transporters and alien life forms. Very seldom does anyone stop and think about how a crew of 400-plus people, on board an enormous starship for a "five-year mission" would feed themselves, keep their clothes clean and in good repair, arrange recreation, manage waste, and maintain their health. Since all elementary students love to eat, the teacher could direct the students in activities designed to help them understand the different ways that technology is employed in food production, preparation and storage, using the students' favorite foods as a basis.

For instance, students could examine contemporary food preparation practices on airplanes to help them make decisions on how such factors as speed, altitude and air pressure might affect certain foods. Sample meals and menus could be obtained at airports, and speakers who prepare and serve such meals could be invited to speak to the children and assist in food preparation activities. Students could design new cooking equipment and methods, keeping in mind such realities as space availability and dietary requirements. On the other hand, some students could simply use computer programs to design meal schedules for a crew of over 400, remembering that no starship could realistically have the facilities to feed them all at once. On a related note, family and consumer science teachers could have students design new processes for laundering and maintaining crew uniforms, since a starship likely would be unable to carry enough water to devote to five years' worth of laundry for over 400 people. Water reclamation is another topic that can be demonstrated through the use of simple, student-designed evaporation and condensation equipment.

In any case, once the students have completed such an activity, they could then write a chapter to one of the novels that adds an episode featuring the use of the technology they have designed.

Activity Two—Life Support

Science teachers could arrange an extended activity centered around the gear used by contemporary Space Shuttle astronauts, or on the spacesuits they wear when they step out into space. As a sidebar, the teacher could review the history of technology used to gather information about other planets, and the ways it has evolved in the past thirty-five years. With such information as background, the students could create an episode in which the starship crew members are beaming down to a planet with a surface atmosphere that does not support human life. The teacher might introduce data on the various atmospheres of planets within our own solar system for the students to use as models. The students would need to think about what kind of protection the crew members would need; then, they could design spacesuits particular to the task.

A perceptive teacher would engage the children in an invention of their own planet, describing its conditions that might or might not support life and constructing the technology that would enable humans to have adequate food, clothing and shelter.

CONCLUSION

These ideas barely scratch the surface of possibilities for activities based in children's literature. Especially in the later elementary grades, ESTE could be integrated into *Star Trek* literature to enhance teaching in mathematics, science and many other disciplines. Appendix A provides guidelines for determining whether an activity is a technology-based activity.

Educators can readily envision scenarios in which technology education could merge with certain disciplines and enhance student learning. Children's literature is not one of the first disciplines technology educators would think of, and yet even within such a seemingly incongruous pairing, the possibilities for enduring learning can be found.

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Section II Programs: Technology Education As Process

OVERVIEW

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A primary purpose of the preceding section of this book is to demonstrate how technological activities in the classroom can deliver, reinforce, and enrich the curriculum, whether the subject is social studies, language arts, mathematics, science, or any other topic. As Childress and LaPorte suggest in chapter 3, however, not everyone views elementary school technology education (ESTE) simply as a method of teaching the traditional curriculum. Technology can also be seen as part of the content of the elementary school as well. Welty's arguments in chapter 6 suggest that the content-method dichotomy is at best an oversimplification and that ESTE can contribute to a child's school experience when it is regarded as a process.

Exactly what the process is depends on whom you talk to. Some say it's design; others see it as problem-solving. A third group sees ESTE as design and problem-solving. And there are other processes. Critical thinking, or higher-order thinking skills in general, has been suggested, as have decision-making, creative thinking, and many other specific skills.

The view of ESTE as a process has a long history, and many modern programs have been built in part or in whole on this philosophy. From the hundreds of students affected by the ESTE program at the tiny Ten Sleep school in north-central Wyoming to the hundreds of teachers affected by Project UPDATE and associated programs in the urban Northeast to the hundreds of schools across the U.S. participating in the Technology Student Association's elementary school program, the ESTE-as-process view is in wide evidence.

Just as the authors of the chapters in Section I do not concern themselves solely with content and method, the authors in this section view technology broadly—yet they all provide a view of ESTE as a process.

Wright and Miller (chapter 9) propose an adaptation of the popular constructivist approach to schooling, for instance, when they describe a K-12 technology education program with strong process and content emphases. They suggest that constructivism is an outgrowth of the works of Piaget and Dewey and that a theoretical connection between constructivism and ESTE is not difficult to establish. This connection can be seen at the program's Center for Applied Learning, which is both a technology laboratory in a traditional sense and a resource center for elementary school teachers. Technology education experiences are carefully articulated throughout the school, but teachers are free to employ technology activities where they see fit. Wright and Miller suggest that the result of implementing constructivism in the classroom will be improved learning across the curriculum.

In chapter 8, Barbato also introduces constructivist theory, as part of his discussion of the Technology Student Association's national ESTE program. Barbato recommends employing constructivist theory to insure that public-school graduates are employable. He argues the need to view students as future citizens and workers, which, he notes, demands that educators accept input from business and industry. This view doesn't contradict Wright and Miller's, but it does point out difficulties in comparing a national, co-curricular program with a single-site program in a remote part of the country.

In explaining the co-curricular nature of TSA's program, Barbato also emphasizes subject-matter integration, focusing particularly on the integration of math, science, and technology (MST). Like Barbato, Welty (chapter 6) and Todd (chapter 7) invoke MST and the science community in discussing ESTE, and believe that technology can provide "practical applications" to illustrate scientific concepts that children should understand. Welty cautions that many of these concepts are difficult even for high school and college students and that the introduction of unnecessarily difficult subject matter can demand the memorization of facts rather then the understanding of principles. Welty's vivid depiction of the elementary school environment shows that ESTE can contextualize the skills really valued in schools—skills like reading, writing, listening, getting along with others and expressing one's self. The goal of Welty's chapter 6 is to provide a foundation for the establishment of technological learning experiences that "maximize the connection between lessons and learning activities."

In chapter 7, Todd also details the view of technology education—which he refers to as the *design and technology*—approach as the basis for schooling. This approach, currently being implemented by teachers on the East Coast and elsewhere in the U.S., is an effort to impart meaning to schoolwork and to promote student self-worth and ownership in elementary school education. The approach as presented here is not a curriculum or a methodology—it's a plan for envisioning the entire school. Like Welty, Todd looks to science education in explaining his approach, although Todd does this in part to demonstrate interest in the design and technology approach outside the field of technology education.

Throughout these four chapters there is a strong message that technology education in the elementary school may have more to offer than just technical content or a means of delivering traditional subjects. The contribution of technology education to the elementary school classroom, then, can be what Welty refers to as "rich." But this can only be, Mossman (1929) reminds us, if we let technology education in the elementary school classroom evolve out of, because of, and alongside the everyday needs and interests of the child and the class.

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Chapter 6 Engaging the Senses in a Quest for Meaning

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Historically, both elementary school teachers and technology educators have taken great pride in meeting the educational needs of students through highly experiential and concrete learning activities. Developing and implementing learning activities is a skill involving the art and science of education. Teachers must tap their imaginations and creative talents to translate abstract and complex concepts into meaningful learning activities that can be implemented with limited resources. In addition, learning activities need to be pedagogically sound to stimulate and motivate students and encourage learning.

The following narrative will describe how learning activities based on the study of technology can be used to address many of the concerns and recommendations expressed by various leaders in education. It will also provide a list of simple guidelines that can help both elementary school and technology educators make informed decisions when designing, developing and implementing learning activities for young people (Welty, 1993; 1990). With the aid of these guidelines, technology and elementary school teachers can pool their expertise to capitalize on the study of technology, which will enhance and enrich the elementary school curriculum with activities that facilitate understanding.

This chapter also includes a series of case studies that support the principles and procedures being proposed for the design and implementation of elementary school technology education (ESTE). Due to their length, these cases have been placed in Appendix B to be referred to while reading this chapter. The case studies can also be used to conduct discussions about ESTE activities in preservice and inservice classes or workshops.

PROBLEMS AND OPPORTUNITIES

Teachers and administrators are addressing several important issues that have plagued elementary school education for years. Among the more pressing problems is the undue emphasis being placed on rote learning, drill and practice activities, and covering content in contrast to facilitating genuine understanding, especially in subject areas such as science and mathematics. Both early and upper elementary school students spend a majority of their time engaged in written activities, listening to lectures and explanations, and preparing sedentary assignments (Goodlad, 1984) instead of being engaged in active modes of learning.

One area of concern is the meager ration of time and energy being allocated to science education. In Goodlad's study of 13 elementary schools (1984), students spent an average of only 2.3 hours per week studying science. According to leaders in science education, far too much emphasis is placed on teaching "factoids" in contrast to doing science (Ahlgren & Rutherford, 1993; Hurd, 1991). These leaders argue that more time should be spent engaging students in modes of learning that involve asking questions about the natural world, developing strategies for pursuing answers, making qualitative and quantitative observations about natural phenomenon, discussing their findings and formulating propositions based on evidence.

The mathematics community is also challenging elementary school educators to enhance the study of mathematics through learning activities that require them to apply mathematical principles and patterns to situations in everyday life (Dossey, 1989; National Research Council, 1989; NCTM, 1989). Elementary school teachers are being encouraged to make the study of mathematics more concrete through the use of manipulatives and authentic problems. Furthermore, they are being asked to make the study of mathematics more consistent with the ways students naturally think about numbers.

With the exception of the active kindergarten classroom, the sedentary nature of elementary school education is one of the more common problems mentioned in recent education reform literature. Elementary school teachers are being encouraged to design and implement learning activities that have meaning beyond the walls of the schools and to use active modes of learning and diverse teaching strategies in order to accommodate a wide range of learning styles. They are being encouraged to clarify connections and relationships between the basic disciplines (AAAS, 1989, 1993; Beane, 1995; Hurd, 1991) in order to engage students in cooperative learning and to employ more authentic assessment techniques (Wiggins, 1993).

The resolution of these concerns will have a profound impact on the way teachers design and implement learning activities. Few teachers would argue with the importance of engaging their students in "hands-on" learning experiences. This section will examine how ESTE can provide learning activities that enrich education.

Form and Function

ESTE can play several important roles in the curriculum. Some leaders in science education have argued that the introduction of technology learning activities into the elementary school curriculum will capture the interest of students, engage them in meaningful thought processes and accommodate a wide range of learning styles (Bredderman, 1987; Pizzini, Shepardson, & Abell, 1989; Shamos, 1982, 1995). These leaders believe that having students engaged in the study of technology will facilitate an interest in and readiness for genuine inquiry into the laws of nature (Bredderman, 1987; Schauble, Klopfer, & Raghavan, 1991; Shamos, 1982, 1995). In addition to complementing the science curriculum, technology itself is a unique and important body of knowledge that should be an integral part of the elementary school curriculum (AAAS, 1989, 1993; Bredderman, 1987; Hurd, 1991; National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983; Shamos, 1982, 1995). Lastly, there is general agreement that the study of technology provides an authentic context for integrating, transferring and applying content throughout the curriculum.

The following sections will describe three roles that ESTE can play in the curriculum. ESTE can be used to: (1) teach concepts that are unique to technology, (2) create contexts that make other aspects of the curriculum more meaningful to young people, and (3) engage students in thought processes that promote the development of higher-order thinking skills. It is important to note that most ESTE activities tend to address all three functions with varying degrees of emphasis.

Technology as Content

The most obvious reason for designing and implementing ESTE is to enable students to develop a basic understanding of fundamental technology concepts and skills. In addition to learning about language arts, mathematics, natural science and social science, students must begin to study technology in order to understand the human-made world that directly impacts their lives. Even though people are surrounded by technology in everyday life, the basic concepts and skills that need to be taught at the elementary school level are not self-evident.

It is very easy for both elementary school and technology teachers to be overwhelmed by the pervasive and dynamic nature of technology. After all, the knowledge base for technology is as old as humankind (AAAS, 1989; Kransberg & Pursell, 1967; Staudenmair, 1989), and some observers believe it is expanding at an exponential rate (Cardwell, 1995; Naisbitt, 1982). While the prominence and growth of technology in society can intimidate some teachers, it can also inspire other teachers to address as many technology topics as time and resources will allow.

To cope with a growing body of technological knowledge, some leaders are recommending that educators adopt the philosophy that "less is more" (AAAS, 1993). Teachers are being encouraged to focus their precious time, energy and resources on developing and implementing learning activities that enable their students to master a modest number of profound understandings in technology.

One of the fundamental premises underlying the principle that "less is more" is the notion that not all the ideas, concepts and skills have equal value in the lives of young people. The knowledge base for ESTE includes broad generalizations that cut across a variety of technologies, as well as specific facts and vocabulary associated with specific technologies. Elementary school and technology teachers who embrace this "less is more" philosophy strive to help children begin to develop a conceptual knowledge base and the thinking skills necessary for a lifetime of building new understandings without concentrating on unnecessary details.

Identifying the key concepts and skills that will provide children a sound foundation for future learning is an extremely difficult task that requires a thorough understanding of the content, and a genuine empathy for students. To develop learning activities that target profound understandings in technology, reflective teachers evaluate their curricula based on the intellectual and emotional needs of their students. Designing learning activities that put the needs of students first demands making distinctions between trivial "factoids" and meaningful understandings as well as between antiquated skills and empowering aptitudes. To define and organize the content for ESTE, teachers find themselves searching for core concepts that provide students the best foundation for future learning. This reflection and analysis process culminates in a need to compose outcome statements that capture the essence of the content, exemplify the teacher's concern and optimism for his or her students, reflect the deliberations that went into the decision-making process and communicate the teacher's wisdom to the school's stakeholders (e.g., students, parents, administrators).

The case studies featured in appendix B describe how three teachers struggled to identify and operationalize the content associated with their learning activities. In all three cases, the impetus for developing a new ESTE activity was a genuine desire to make a given unit of instruction more meaningful and exciting. Once the topics were identified all three teachers tried to articulate the technological understandings that they wanted their students to possess at the end of the laboratory activity. The case titled "Operation Oil Spill" describes one teacher's effort to target generalizable concepts through the study of a current topic in the news while the teachers in the other two cases, "Pop Can Solar Collectors" and "WKID Radio", targeted more specific outcomes.

Identifying content for ESTE is very time consuming and intellectually exhausting. Most classroom teachers do not have time in their schedules to unearth the assumptions that underlie their curricula and engage in a disciplined analysis of the content associated with ESTE. With the support of national organizations, several communities of educators have assembled standards for public education that address ESTE. The two most popular sources for technology standards at the elementary school level are Benchmarks for Science Literacy (AAAS, 1993) and National Science Education Standards (National Research Council, 1996). The use of these standards can provide classroom practitioners a head start in their effort to identify meaningful content.

Technology as Context

Many topics in technology are too sophisticated for elementary school students to genuinely understand. Although the students may not be ready to study a given technology in detail, the topic can still be used to provide a rich context for making other concepts and skills in the curriculum more relevant, interesting, and ultimately, more meaningful.

To encourage higher-order thinking and not just rote learning, John Dewey (1938, 1966) suggests that school curriculum should be based on situations that present themselves outside of school and fall within the scope of ordinary life experience, which gives "pupils something to do, not something to learn; and the doing [being] of such a nature as to demand thinking, or the intentional noting of connections; [so] learning naturally results" (p. 154).

Life is full of problems that require people to use what they have learned in school. They must apply concepts and skills from a variety of disciplines. Learning activities organized around interesting people, enterprises, and activities using technology can help to address the problems in everyday life and can help students discover the interrelationships between their school subjects and their relevance in everyday life and work. It is fun for students to experience new ideas and concepts while role–playing people performing tasks in the adult world. A short interview with a young person about their favorite collection (e.g., dolls, baseball cards, books, rocks, etc.) will confirm the proposition that children have a tremendous capacity to learn about the things that they enjoy.

In the case titled "WKID Radio," (page 371) the study of broadcasting technology was perceived to be too sophisticated for young learners. Furthermore, it was clear that the technological concepts associated with radio intimidated the teacher. However, the notion of simulating a radio station in the classroom using a simple electronic toy provided a rich context for teaching and reinforcing a wide range of concepts in the curriculum. The radio broadcasting project provided students an opportunity to actively apply things like public speaking, creative writing, music and current events to something important in their lives outside of school. The nature of the ESTE activity also encouraged students to develop an appreciation for what was taught in school.

Technology as Process

One of the goals of public education is to help students develop higher-order thinking skills. Both technology and elementary school teachers strive to help their students become skillful problem-solvers, creative thinkers and good decision makers. To enable students to develop these skills, teachers can use ESTE activities to provide their students opportunities to break ideas, problems and phenomena into pieces; to explore each piece and discover relationships between the pieces; to generate new and creative ways to put pieces together; and to select the best arrangement of pieces. One of the more popular strategies used to promote higher-order thinking skills is to engage students in designing solutions to problems.

Since the mid–1960s, technology and elementary school teachers in the United Kingdom have been experimenting with the concept of design as a teaching strategy. They have discovered that learning activities that engage students in the design process can play an important role in the elementary school curriculum (Dunn & Larson, 1990; Kimbell, Stables, Wheeler, Wosniak & Kelly, 1991; Murry, 1990; Todd & Hutchinson, 1991; Welty, Valenzuela, Brearley, Ezell, Matthews, McGirr, Rossman, Sharp & Vincent, 1991). Furthermore, there is a feeling among these educators that the curriculum would be incomplete without a design component.

At the elementary school level, teachers play an integral role in facilitating and directing the design process. For students to experience success, teachers may need to provide the problem and even suggest some strategies and techniques to develop a viable solution. The design problem needs to be very concrete and within their realm of experience. At the elementary school level, the design process will have only a few simple stages and students will typically progress through these stages in a sequential fashion. For example, an elementary school teacher might structure a design activity that asks students to look at a problem posed in a piece of children's literature, think of a solution to the problem, make a model of their solution using simple materials and share it with the rest of the class (Brusic, 1992; Todd, 1994).

Young children are very creative and uninhibited in their thinking. Nonetheless, when given a problem to solve, they typically want to develop the first idea that pops into their minds without considering many (if any) alternative solutions. Under the guidance of a teacher, a small group of young children can generate a wide range of creative ideas.

As students gain experience, they often become more involved in identifying problems within a given context, and the design loop will have more stages (Brusic, 1992). For example, an elementary school teacher might ask students to identify a problem within a given context, define the specifications and resources available for developing a solution, brainstorm alternative solutions, assess the merits of the alternatives and identify the best solution and evaluate the final solution against the design specifications. With teacher guidance, students would examine their solutions based on a modest list of criteria.

One area of concern associated with using design-oriented ESTE is the tension that can emerge between the student's interest in developing a solution to a captivating problem and the teacher's desire to capitalize on the design problem to introduce new concepts–concepts that students may or may not perceive as essential to the solution of their problem (Welty et al. 1992). Another area of concern is the distinct possibility that many students will develop successful solutions to design problems without a deep and accurate understanding of the concepts that contribute to the solution. One way to address these problems is to place more emphasis on the *process* of design rather than the *products* of design. In contrast to assigning grades based on the quality of the final product, the assessment process needs to focus on the students' thought processes as they design and their understanding of the key concepts associated with the design problem.

Emphasizing the design process over the design product will also address specific objectives (Welty, et al. 1992). For conceptual learning to occur, teachers will need to create a climate that encourages students to ask questions, to conduct systematic investigations and to defend their design decisions with evidence. The working climate of engineers, designers and architects could provide a valuable model for creating learning environments that demand good design.

DESIGN CONSIDERATIONS

As previously mentioned, developing meaningful ESTE activities is a difficult and time-consuming undertaking for even the most knowledgeable and creative teacher. The ESTE design process is fraught with perplexing decisions and inherent compromises. Although there is no such thing as a perfect learning activity, there are appropriate and inappropriate learning activities, efficient and inefficient learning activities, and ultimately, effective and ineffective learning activities. To make an activity as appropriate, efficient and effective as possible, both elementary school and technology teachers need to ask themselves difficult questions, consider a variety of alternatives, engage in action research and make informed decisions. The following section will propose a series of design principles and questions that can be used to guide and inform the learning activity development process.

Conceptually Rich

Curriculum reform has been an important topic in the professional literature since the publication of A Nation at Risk by the National Commission on Excellence in Education in 1983. One of the more prominent recommendations in the literature of AAAS (1989), Brophy & Alleman (1991), Brooks & Brooks (1993), Gardner (1991), Peterson & Knapp (1993) and Marzano (1992) is the need to teach for understanding in contrast to rote memorization. Curriculum theorists are also recommending that more emphasis be placed on how concepts are applied in everyday life in hopes of making the curriculum more meaningful to young people (Brophy & Alleman, 1991; Gardner, 1991; Pate, McGinnis & Homestead, 1995; Marzano, 1992). Responding to these challenges will mean developing learning activities to engage students in a cognitive journey that leads to genuine understandings. Unfortunately, many so called "hands-on learning activities" are often implemented for the sake of engaging students in an activity and not for the sake of students' achieving predetermined objectives (Brophy & Alleman, 1991; Wurdinger, 1990). These types of learning activities tend to be an end in themselves.

The primary purpose of a learning activity is to help students learn an important body of knowledge. Therefore, ESTE activities need to be conceptually rich. They need to be designed around topics that intrinsically contain a wealth of important concepts and essential skills. All three case studies, provided in Appendix B, describe a teacher's attempt to address topics that contain a breadth of concepts and skills. Especially in "Operation Oil Spill" (page 353), the narratives describe the teachers' efforts to identify and target a handful of understandings that they felt were especially important for students to master.

Before implementing a new ESTE activity to address topics that contain a breadth of concepts and skills, teachers may want to answer the following questions. Positive responses to these questions indicate a conceptually rich learning activity that will play an important role in a teacher's curriculum, as well as a crucial role in a student's journey toward technological literacy.

1. Does the proposed learning activity target important concepts and skills in the school's curriculum?
2. Does the learning activity build on prior knowledge and skills?
3. Does the learning activity encourage students to think about the nature of the content (e.g., relationships between concepts)?
4. Will the learning activity help prepare students to learn more sophisticated concepts and tasks in future lessons?

Conceptually Transparent

ESTE activities should strive to take the mystery out of technology. Too often, technology is presented to students as a series of magical devices that accept inputs from users and produce impressive outputs. Developing conceptually-transparent learning activities involves breaking technological topics down into their simplest form and using appropriate materials and manipulatives to illuminate and reinforce key concepts. For example, in the case titled "Operation Oil Spill," students used very simple materials to contain, collect and disperse oil in a small tub of water. These modest materials enabled the students to have a direct experience with the complexities of removing contamination.

At first, many important topics in technology appear to be too sophisticated or expensive to address with hands-on activities. Instead of omitting these topics from the curriculum, creative teachers find ways to present abstract concepts and complex technologies that are meaningful to students. This task involves identifying the essence of a given technology and finding simple manipulatives that can be used to model the technology in a manner that is easy to understand, without compromising the factual accuracy of the lesson or imprinting misconceptions in the mind of the learner. When a given learning activity is conceptually transparent, students are likely to say things like "so that's how it works," "this is really simple when you think about it," or "it's easy to understand when it's presented in this way." Once a basic understanding has been established, subsequent learning experiences can be based on more sophisticated and representative hardware.

The following questions can be used to evaluate the conceptual transparency of a given learning activity.

1. Will students find the learning activity illuminating?
2. Does the learning activity enable students to experience the content in the least threatening way possible?
3. Does the learning activity allow students to experience the content without undue attention to specific or trivial details?
4. Does the learning activity allow students to experience difficult concepts and skills in incremental and easy-to-learn pieces?

5. Does the learning activity encourage students to focus on the essence of the content being addressed in the lesson (e.g., key concepts, the big picture, generalizable concept, etc.)?
6. Will the learning activity take the mystery out of technology (e.g., discover what is happening inside the "magic black boxes")?
7. Will a vast majority of the students be able to perform the learning activity with some degree of success?

Contextually Authentic

One of the basic purposes of progressive education is to prepare young people for life. To fulfill this mission, advocates for progressive education argue that the curriculum should be derived from life and all its manifestations (Whitehead, 1952). Unfortunately, life in a public school classroom has little in common with life outside of the classroom. One of the strategies being proposed for making schooling more effective and meaningful is to make the public school curriculum more authentic (Brandt, 1993). According to some researchers, creative teachers can capture the attention and arouse the curiosity of their students by designing and implementing learning activities that require students to apply new knowledge in contexts that are important to students in their lives outside of school (Brophy, 1987; Marshall, 1987; Perrone, 1994; Pizzini, Shepardson, & Abell, 1989). "Operation Oil Spill" and "WKID Radio" exemplify efforts to capitalize on things that students care about or find interesting.

Integrating ESTE does not automatically guarantee the curriculum will be more authentic. Special care has to be taken to make sure that the technology being used to authenticate the curriculum is being accurately represented. It is easy for industrious elementary school teachers to develop learning activities that misrepresent technology.

The following questions can be used to evaluate a learning activity's contextual authenticity. The answers to these questions can also suggest opportunities to improve the activity and make it more meaningful in the students' lives.

1. Is the learning activity relevant in the lives of the students being served?
2. Does the learning activity capitalize on real problems or situations that present themselves in everyday life or the world of work?
3. Will the learning activity provide students a vicarious experience in an important aspect of life or an occupation? More simply, will they feel as though they sampled a genuine slice of life or the world of work?
4. Will the learning activity capitalize on the language, symbols, conventions or artifacts used in everyday life or the world of work?

Highly Experiential

ESTE activities should engage the students' senses in a quest to understand the human-made world. In contrast to the sedentary learning activities that dominate elementary classrooms (Goodlad, 1984), technology learning activities typically require students to actively use their hands and minds to design something, build something and/or test something. When compared to other modes of instruction, teachers and students alike tend to report that hands-on activities are more interesting and fun. There is a modest body of evidence that suggests hands-on activities promote higher achievement in elementary school science education than textbook-based instruction (Bredderman, 1982; Shymansky, Hedges & Woodworth, 1990; Shymansky, Kyle & Alport, 1983). Teachers need to translate their learning objectives into activities that stimulate the students' interest and imagination, transform abstract concepts into concrete learning experiences and provide students an opportunity to be successful.

One such method is to frame learning activities in the context of a design problem. Students are asked to identify and analyze a problem, gather information regarding the problem, develop a variety of potential solutions to the problem, select and refine the best solution for the problem, describe the solution to the problem in detail, build and test a prototype and present the solution to the problem to others.

Another approach is called *guided inquiry*. With this strategy, ESTE is presented in the form of laboratory activities designed to help students discover and experience technical and scientific concepts. The first step is to introduce students to the key concepts associated with the topic during a short teacher-guided discussion. Next, the teacher demonstrates how to use the tools, materials and equipment needed to perform the laboratory activity. After their questions have been addressed, the students conduct the laboratory activity by following a list of procedures that asked students to gather and interpret data. Upon completion of the laboratory activity, students are typically required to present their results in the form of a written and/or oral report. This approach is often used to structure laboratory activities regarding topics like electricity, simple machines, light and plant science.

Last, but by no means least, simulations can play an important role in the elementary education curriculum. This technique is especially appropriate when trying to address large–scale topics that are impossible to replicate in the classroom (e.g., oil spills, radio broadcasting, etc.). This technique uses role playing, modeling techniques or computer-aided instruction to help students experience and learn important concepts. All three case studies utilize the concept of conducting a simulation to address difficult technology topics.

Time and Cost Effective

Teachers need to design technology learning activities that make appropriate use of both time and money. In general, the amount of time allocated to a given topic should be in direct proportion to its value in the lives of the students being served. Most school districts are experiencing financial difficulties. Elementary teachers have very modest budgets that often do not adequately address everyday consumables, much less expensive manipulatives for technology activities. This means spreading precious financial resources across a variety of topics, based on their importance in the lives of the students being served.

Answering the following questions will help a teacher insure that a given learning activity is time and cost effective.

1. Is the amount of time required to perform the learning activity in proportion with the significance of the concepts and skills being addressed?
2. Are the costs associated with implementing the learning activity in proportion with the significance of the concepts and skills being taught?
3. Will the activity allow students to stay on task most of the time (e.g., students do not have to wait for glue to dry or wait in line for equipment)?
4. Will the students be able to perform the activity without having to spend undue time learning how to use specific tools, materials, hardware or software?
5. Will the implementation of this learning activity compromise one's ability to implement other equally, if not more important learning activities?
6. Will the learning activity take time away from equally, if not more important curriculum topics?
7. To what extent can the learning activity be replicated in the future without incurring additional cost?
8. Can the cost of facilitating the learning activity be absorbed by parents or an organization in the community?

Intrinsically Synergistic Interdisciplinary Education

ESTE activities need to be efficient from a curriculum and instruction perspective. One way to think about integrating ESTE into the curriculum in an efficient manner is to strive for synergy. Synergy is achieved when the whole is greater than the sum of its parts. Students are able to experience and learn more when the concepts and skills are linked and taught together than they would if all the concepts and skills were isolated and taught separately (Beane, 1995; Fogarty, 1991; Jacobs, 1989; Palmer, 1992).

A variety of strategies can be used to maximize continuity within and across the elementary school curriculum. One of the simplest is to maximize the connections between lessons and learning activities. Another strategy is to design ESTE activities in a manner that provides students with a sense of continuity from one lesson to the next (e.g., Ahlgren & Kesidow, 1985; Fogarty, 1991). The third and comparatively sophisticated strategy is to facilitate interdisciplinary education. This third strategy is the focus of this section.

According to Heidi Jacobs (1989) interdisciplinary education is "a curriculum approach that consciously embraces and applies concepts and skills from more than one discipline while addressing a central theme, issue, problem, topic, or experience" (p. 8). Complementing and reinforcing academic skills and concepts is an important agenda in the technology education curriculum. It is important, especially in times of back-to-basics and education reform, to identify and maximize opportunities to introduce or reinforce academic skills and concepts during the learning-activity design process.

There are several potential pitfalls associated with interdisciplinary teaching and learning. The first one is called the *potpourri phenomenon*, wherein a integrated learning experience provides students with a superficial sampling of important concepts and skills associated with a discipline (Jacobs, 1989, p. 2). Another potential pitfall is called the *polarity problem*. This dilemma can surface when educators whose allegiance to a given discipline is so strong that they are unwilling to share content with others or do not trust others to represent their discipline in a responsible manner (Jacobs, 1989, p. 2). The last potential pitfall is *content integrity*, where a teacher gets caught up in the process of integrating the content at the expense of the integrity of the curriculum (Ackerman, 1989).

The following questions can be used to evaluate the interdisciplinary merit of a potential learning activity.

1. Are the concepts and skills being associated with the integrating theme, problem or essential elements in the curriculum?

2. Would the same content be considered even if the curriculum wasn't being integrated?

3. Will learning be genuinely enhanced by integrating the concepts in contrast to teaching them separately?
4. Is the content maintaining the integrity of the represented specific disciplines in the integrated learning experience?
5. Will the integration of concepts and skills provide students a unique perspective that would not be possible without integration?
6. Is the whole (e.g., total experience) greater than the sum of its parts (e.g., discipline–specific experiences)?

DEVELOPMENTALLY APPROPRIATE

It is easy for novice technology teachers to believe that elementary school children can learn relatively complicated concepts as long as they are broken down into small and sequential pieces and each piece is clearly explained. In reality, research suggests that many young children are not inherently able to grasp some concepts regardless of how clearly they are presented (AAAS, 1993; Piaget, 1970). Some researchers believe the elementary school curriculum currently strives to teach children topics that are beyond their ability to truly understand. Technology and elementary school teachers need to design and implement learning activities that are consistent with their students' physical, social and intellectual development.

Preschool and Kindergarten

Children are physically active in preschool and kindergarten. Due to their propensity toward spurts of energy, preschool and kindergarten students need frequent rest periods. In addition, the students' enthusiasm and excitement for kinesthetic activity can escalate into a chaotic situation. Teachers should develop learning activities that provide these students opportunities for running, climbing and jumping but that have adequate structure and provisions for pacing. Sedentary activities should be scheduled after energetic ones.

At this young age, the children have better gross motor skills than fine motor skills and find it difficult to focus their eyes on small objects. Thus, their eye-hand coordination may be awkward. Learning activities designed for preschool and kindergarten children need to based around larger manipulatives that are easy to put together and take apart. An effort should be made to avoid materials that require attention to small details.

In terms of their social characteristics, most of the children will have one or two best friends, but they are typically willing to play and work with others. Their groups tend to be small and not highly organized and are subject to sudden changes. Although the students can work together, children at this age rarely work collaboratively to complete a given task. Younger children are egocentric and they believe that others perceive things the same way they do (Piaget, 1970). Teachers should design ESTE around the concept of parallel play. Students should be asked to complete their own projects while working in proximity of one or two peers.

Preschoolers and kindergartners enjoy dramatic play and most of their plots are derived from their own experiences or things that they have seen on television. Teachers should try to capitalize on these experiences when they are designing learning activities. The learning activity should include provision for managing the enthusiasm that is likely to emerge when children are able to identify with the context in which the learning activity is being implemented.

Preschool and kindergarten children are inclined to express their emotions freely and openly. Spontaneous outbursts of anger and frustration are frequent and usually occur when the children are hungry or fatigued. They will also show signs of stress if they have been subjected to too much adult interference. Peer rivalries are relatively common at this age. Both preschool and kindergarten children are often very fond of their teacher and they actively seek his or her approval. It is important to develop learning activities that allow the teacher to spread his or her attention around the room as equally as possible. It can potentially be disastrous to design a learning activity that requires the teacher to be in one place more than any other or to work with one group of students more than any other.

Young children like to talk, especially in front of a group. Early childhood teachers like to provide their students time for sharing things to help them develop speaking and listening skills. It is often a good idea to build a little "show and tell" segment into technology activities for students in this age group. Children can be very imaginative and inventive at this age, being in Piaget's pre-operational stage of development (Piaget, 1970). Therefore, do not be surprised if a few carefully composed questions are needed to help students distinguishing between reality and fantasy.

Grades One Through Three

Elementary school children in the primary grades are physically active but have learned to modify their behavior when occasion demands. Now that they are in a more traditional classroom, they are often participate in sedentary activities but find it difficult to sit still for long periods of time. Learning activities that allow students to get out of their seats are a welcome change of pace. Organization and structure are still very important considerations when implementing activities that involve more active forms of learning.

Their gross motor control is still better than their fine motor coordination, so many children may find it difficult to use things like pencils, scissors and tape. Since their eyes are still developing, some of the students may have difficulty focusing on small print or objects. Quite a few children may be far-sighted because of the shallow shape of the eye. It is very important to select materials that are easy to manipulate. ESTE documentation should feature larger type and lots of space for writing and drawing.

Students can become easily fatigued from the mental and physical activities associated with school life, and they will still need rest periods. These quiet times provide teachers a modest amount of time to prepare and set up hands-on learning activities.

At this age, students want to be industrious and produce things (Erikson, 1968). They are beginning to be able to develop a mental image of what they want their work to look like when it is finished. Unfortunately, they often have difficulty making things in reality as well as they have composed them in their minds. It is very easy for students to become frustrated with their work and adopt a negative attitude about their abilities. It is not uncommon for students to begin announcing that they are not good at a given skill, that they do not know how to do something or that they can't do a given task. Criticism of their work can lead to a feeling of inferiority within the learner (Erikson, 1968). Teachers need to design learning activities that provide students opportunities to experience success, especially in their own eyes.

Children have left the pre-operational stage and are now in the concrete operational stage of their cognitive development (Piaget, 1970). Hands-on learning activities are very effective modes of instruction for this age group. However, it is difficult for students to process more than one variable at a time, and extremely difficult to process abstract ideas. Learning activities designed for this age group should target one concept or skill at a time. They should also be as concrete and tactile as possible.

Grade Four Though Six

Students have good fine motor skills by the time they reach the upper elementary-grades. Most of the children will find the manipulation of small objects easy and enjoyable. Although some children are entering the stage of formal operations, they are still concrete thinkers who learn by directly experiencing the world through their senses (Piaget, 1970).

At this level children become somewhat more selective in their choice of friends. They are likely to have a more or less permanent best friend and may also pick out an adversary within their class. During this age span, children often like organized activities that allow them to work in small groups. They begin to gravitate toward all boy and all girl groups. They are beginning to realize other people have different points of view (Piaget, 1970). Consequently, a variety of cooperative learning strategies can be incorporated into hands-on activities, and students can begin to work in teams to complete a given task.

Children at this age can become overly concerned with the rules associated with a given learning activity. Most of the children are still moral realists and find it difficult to understand how and why rules should be adjusted in special situations (Piaget, 1970). The idea of fairness dominates much of their thinking. Equity is an important consideration when designing learning activities for this age group. All the students should have equal access to tools and materials.

Elementary school pupils are usually eager to answer questions whether they know the answer or not. They often formulate answers to questions by thinking out loud. Most students like to engage in class discussions.

Elementary school children often are curious about almost everything. It is very common for students to begin collecting things and suddenly drop that interest in favor of another. The curriculum should allow students to sample many different activities. These learning activities should be designed so they can be completed in one or two class periods, and larger activities should be divided into small and discrete chunks.

Differences between boys and girls are also beginning to emerge at this age (Restak, 1979). Girls' fine motor skills develop faster than the boys, and girls tend to have more success with language skills. Learning activities need to be designed so both boys and girls have rich experiences with both spatial and verbal phenomena. Students should not be allowed to gravitate towards tasks that are consistent with their strength at the expense of developing other skills and aptitudes. Lastly, gender–neutral language should be used throughout the learning activity and every effort should be made to avoid gender stereotypes.

The following questions can be used to insure a given learning activity is developmentally appropriate.

1. Is the amount of time required to perform the activity consistent with the student's attention spans?

2. Are the tasks that the students will be asked to perform consistent with their fine motor skills?

3. Is the learning activity designed in such a manner that the teacher can give all the students an equal amount of attention?

4. Is the concept load associated with the learning activity consistent with the students' cognitive abilities?
5. Do the students have an experience base on which new concepts and skills can be developed?
6. Are students being grouped in a manner that is consistent with their social and emotional development?
7. Does the learning activity instigate or perpetuate social gender roles or stereotypes?

PEDAGOGICALLY SOUND

As noted earlier, hands-on learning activities are an important part of a rich curriculum and learning environment. Hands-on learning activities, however, are not intrinsically sound, from a pedagogical view. A room full of elementary school students can spend hours engaged in a variety of interesting and entertaining activities without increasing their understanding of the natural or human-made world (AAAS, 1993). To facilitate genuine intellectual growth, learning activities need to be more than just tactile and enjoyable experiences for young people. They must be designed so that they achieve predetermined goals based on the intellectual and emotional needs of the students as well as the nature of the content being targeted.

In contrast to being dispensers of knowledge, teachers are being encouraged to think of the themselves as facilitators of learning (Brooks & Brooks, 1993; National Research Council, 1996; Yager, 1991). As facilitators, teachers solicit information from their students to develop ways to introduce new concepts and skills, so their students perceive these concepts and skills to be relevant in their lives. Advocates of constructivist pedagogy believe genuine learning is more likely to occur in a climate where students believe there is a need to learn the targeted concepts because the concepts can be applied to situations beyond the walls of the school.

In addition to gathering information about their students interests, constructivist teachers also gather information about the students current understanding of the concept in question (Brooks &

Brooks, 1993; National Research Council, 1996; Yager, 1991). They try to determine their students' readiness to learning a new concept and to uncover any misconceptions their students may have about the concept being introduced. With this baseline information, the teacher is better equipped to orchestrate learning activities that will require students to confront their misconceptions and inspire them to revise their constructs based on new experiences.

Teachers using a constructivist approach tend to view their students as partners in the teaching and learning process (Brooks & Brooks, 1993). They strive to create a climate where their students' experiences and notions about how the world works are valued and perceived to be a foundation for further learning. Students are actively encouraged to pose questions and propose explanations related to the topic being studied. The students play an active role in identifying information resources, planning investigations and gathering the information needed to address their questions and validate their explanations. A Socratic dialog dominates the interactions between the teachers and students in constructivist classrooms (Brooks & Brooks, 1993; National Research Council, 1996; Yager, 1991).

Lastly, a variety of evaluation techniques, including authentic assessment, are employed in a constructivist classroom. Students are asked to apply their knowledge to new situations that are consistent with the ways knowledge is used outside of school (Wiggins, 1993). The evaluation process also includes provisions for students to reflect on new experiences and information (Raths, 1987) and to conduct self evaluations (Yager, 1991).

The constructivist approach challenges teachers to guide students in the construction of knowledge for themselves. The following questions can be used to help teachers design learning activities that help students become active participants in the teaching and learning processes.

1. Is the learning activity presented in a context that is consistent with students' experiences, goals or interests?

2. Are students active participants in the identification of a question that needs to be answered or a problem that needs to be solved?

3. Does the learning activity utilize a lot of questions to guide the learning process?

4. Does the learning activity require students to ask questions, propose explanations, design a solution to a problem and/or make predictions?

5. Will the learning activity require students to identify sources of information, gather the information that they need to answer their own questions, validate their explanations, test their designs and confirm or refute their predictions?

6. Are students required to use the concepts and skills being addressed in a situation that is perceived to be important outside of school?

7. Does the learning activity include provisions for students to reflect on their experiences and make judgment about their progress?

OPERATIONALLY FEASIBLE

A technology learning activity has little value in the elementary school curriculum if it cannot be implemented with relative ease. Like most teachers, elementary school teachers need to be very organized to be effective. In order to fulfill their students' need for security, most elementary school teachers have an established routine that they follow very closely. Furthermore, they often rely on their students to help make transitions from one subject or activity to the next. That is to say, the learning activities should be designed and organized so the teacher can conduct the activity with little or no difficulty. Use the following questions to assess the operational feasibility of a given learning activity.

1. Can the room be set up for the learning activity with a minimal amount of disruption?

2. Will all the students have specific roles to play and tasks to perform (e.g., work with materials, record data, etc.)?

3. Can the classroom be restored to its original condition in a minimal amount of time?

4. Can the students assist in the set-up and clean-up processes?
5. Can students perform the learning on the existing work surfaces in the classroom (e.g., tables, desks, the floor, etc.)?
6. Can the learning activity be successfully implemented with the existing utilities in the room (e.g., sink, electrical outlets, etc.)?
7. Can the tools, materials and supplies, as well as the student projects, be easily stored in the room until they can be completed or taken home?

THE LEARNING ACTIVITY DESIGN PROCESS

In practice, ESTE activities tend to develop slowly over time. More often than not, learning about an interesting technology topic, formulating learning objectives, identifying appropriate tools and materials, defining an implementation procedure, designing hardware and developing student handouts tend to evolve simultaneously. A single learning activity may be ready for implementation only after dozens of hours have been spent on it.

Like many design projects, developing learning activities is replete with infinite possibilities and inevitable compromises. During the development process, teachers often find themselves struggling with ambiguities, generating alternatives and searching for solutions to difficult problems. Although the various parts of a learning activity tend to evolve together, there is a basic "underlying" sequence of events that can be used to guide the development process.

The first step in the learning activity design process is to identify and study the topic that will be the subject of the proposed learning activity. The next step is to develop a conceptual model or paradigm that describes the key concepts that will be taught during the proposed learning activity. At this point, teachers may want to begin developing the objectives for the learning activity. Using the conceptual model or paradigm as a guide, identify simple and appropriate manipulative material that can be used to bring the concepts to life.

Curriculum Analysis

ESTE activities should be designed to fulfill a specific need in the school curriculum. Defining this need are goals or objectives that teachers would like their students to achieve during a given unit of instruction. More simply, learning activities are a means to a desired end.

The inspiration for a new learning activity might be a goal or objective that is not being adequately addressed. For example, student evaluations might suggest that the old learning activity is proving to be an ineffective method for helping students understand an important concept or develop a desirable skill. A second reason for designing a new learning activity is that the current learning activity is inefficient because its implementation requires too many resources (time, money, people, etc.). Another reason for developing a new learning activity is a desire to do something new and exciting with children. All three case studies in Appendix B began with a teacher's desire to make learning more meaningful for students. In all three cases, an effort was made to insure that the learning activities eventually targeted important goals and objectives in the curriculum.

Once the need has been identified, the next step is to define the content that has to be taught. The content is derived from the topic and a variety of resources that can be used to define and operationalize the concepts and skills that need to be taught. Curriculum guides, journals, textbooks, trade books, experts in the field and the teacher's knowledge and experience can play an important role in the content identification process.

The next step is to identify the context that will be used to frame the learning activity. In the interest of making the curriculum meaningful, the context for framing and presenting a technology learning activity needs to be derived from everyday life. It can be inspired by a job that someone performs in the community, a pressing social or environmental issue in the media or a practical example from everyday life that is presented in textbooks.

Gathering Information

The process of gathering and synthesizing information is one of the most important tasks in establishing a rich learning environment.

With recent growth in information technology, it is easy for teachers to become overwhelmed. Teachers do not have time to sort through all the information that is at hand. It is easy for elementary school teachers to become frustrated with the technical vocabulary that is used in many on-line and hardcopy publications.

In the interest of efficiency, teachers need to capitalize on the work of writers who have invested a lot of time and energy in reviewing the technical literature, identified and synthesized the important concepts, and composed narratives and illustrations that are easy for the non-technologist to read and comprehend. One of the more important resources in a teacher's library is trade books. Fortunately, there is an abundance of trade books on the market for a wide range of technology topics. Many of these books follow the theme of "how things work."

Technology trade books often provide very simple and easy–to–understand explanations for common technologies (e.g., telephones, televisions, robots, power plants, computers, etc.). They typically feature colorful illustrations to help children make sense of a given technology. There is an inherent danger in relying on one or two books too heavily. Teachers should try to review several books and synthesize the authors' explanations in order to accurately identify and understand the basic concepts associated with a given technology.

Conceptualizing the Topic

Technology is becoming more sophisticated, more specialized and more difficult to understand every day. When trying to depict modern technology, pictures often speak louder than words. Conceptual models or paradigms can identify major concepts and illustrate the relationship between concepts. Reducing complex technological devices, systems and processes to simple diagrams can help a teacher zero in on the essence of what students need to understand. These diagrams can serve as advance organizers to help students form conceptual frameworks where they can organize new bits of information. Once the bits have been organized and assimilated into larger ideas, students will have formed accurate concepts about the technological device, system or process. These concepts can often be used to understand other technologies in future investigations.

After the essential concepts have been identified and categorized, the model can be modified or refined, so it is more meaningful to students. This process might include things like changing the names of the generic headings and/or making the model look more like a pictorial representation of the technology in question. When the conceptual model is finished, it can be featured on student handouts, transparencies and displays.

Selecting and Configuring Hardware

John Dewey (1966) felt that conventional classrooms are "hostile to the existence of real situations of experience" (p. 155). He argued that classrooms must have "more actual material, more stuff, more appliances, and more opportunities for doing things" (p. 156). Transforming classrooms into rich learning environments that can support ESTE involves identifying and configuring hardware, the things that Dewey called "material," "stuff" and "appliances."

A lack of monetary resources is one of the reasons why elementary school teachers are dependent on textbooks and worksheets to facilitate learning. Engaging students in more active forms of learning requires expensive manipulative materials. For the purposes of this narrative, these materials can be grouped into two basic categories: reusable tools and manipulatives, and consumable supplies. Reusable tools and manipulatives are things like rulers, scissors and Legos® that are one-time expenses and can be used over and over again. Consumables are things like tape, glue and poster board that can be used only once.

Both kinds of materials can be a problem for most elementary school teachers. Reusable tools and manipulatives require a large initial investment. Although consumables tend to be less expensive at first, they need to be replenished year after year. With consumable materials a large portion of the budget is being used to maintain the curriculum instead of enhancing the curriculum. Teachers must review what is available in the marketplace, develop and disseminate wish lists for parents, save and scrounge materials, make thoughtful decisions, follow bureaucratic purchasing procedures and organize a storage system.

Elementary school and technology teachers can be very creative in their efforts to cope with the financial realities associated with public education. Among the more commonly used strategies is asking parents to provide a modest number of consumable materials at the beginning of the year as school supplies. Another strategy is to design ESTE activities around recyclable materials (e.g., plastic containers, Styrofoam trays, paper towel tubes, paper bags, etc.). Lastly, some ambitious teachers solicit donations from individuals and organizations in their communities. The case studies in Appendix B illustrate how all of these strategies can be used to facilitate active forms of learning.

Once the tools and materials for a given learning activity have been secured, the next step is to engage in a little tinkering. The tinkering process typically progresses from informal experimentation to thoughtful configuring of hardware to make the learning activity as efficient as possible. In the interest of facilitating learning, the central goal is to consider alternatives, to make informed decisions, to identify and reduce obstacles to success, to anticipate problems and to simplify the hardware. The case of the "Pop Can Solar Collectors" (page 362) and "Operation Oil Spill" (page 353) describe the brainstorming, tinkering, evaluation and refinement that can be invested into learning activity hardware.

Developing Documentation

ESTE activities should be documented for a variety of reasons. Developing a written scenario of learning activities allows the developer to test ideas on paper before using precious class time. In addition, good documentation, which includes handouts, can help students feel more secure during the learning process and experience success. Lastly, learning activities that have been adequately documented can be shared with colleagues. When ideas are properly documented, they can make a significant contribution to the education of young people beyond the walls of one's school. In contrast to trying to reinvent the wheel, sharing ideas on paper allows teachers to focus their attention on implementation and meeting the unique needs of their students. Each teacher who implements a learning activity brings a new perspective to its development and takes it to a higher level of refinement. Well-documented learning activities not only make a significant contribution to the education of young people but also make a significant contribution to the profession.

Documentation should feature a content abstract, describing the key concepts represented in the learning activity; a list of learning objectives; a list of the resources, tools and materials needed to implement the learning activity; a list of procedures for implementing the learning activity and a student handout. If the tools and materials are not available in popular retail stores, a list of potential sources should also be provided. The student handout should enable the student to perform the learning activity with a minimum of teacher assistance.

When documenting learning activities, try not to leave important ideas between the lines. It is easy for experienced educators to take important aspects of a learning activity for granted. Providing too much information is far better than not providing enough. Lastly, do not rely solely on a narrative description when a drawing or picture can be used to communicate important details (e.g., see the drawing accompanying the "Pop Can Solar Collectors" case study.)

Testing

Once the manipulatives and documentation for a learning activity have been developed, it is ready for pilot testing with students. New learning activities rarely work perfectly the first time around. During the pilot-testing process, teachers need to watch and listen to their students very carefully. Students are often a source for ideas to improve the learning activity as they make discoveries that were not listed in the objectives.

In the spirit of action research, it is a good idea to develop assessment strategies. Using your objectives as a guide, develop and administer a formal pre- and post-test to determine if the learning activities contributed to the students' knowledge base. Simple surveys can also be developed to solicit the students' perceptions about the learning activity (e.g., interesting or boring, relevant or irrelevant, easy or difficult, etc.). Finally, modify or refine the documentation of the learning activity based on test scores, feedback from your students and your observations.

SUMMARY

Hands-on learning experiences are clearly an essential and integral part of the technology education curriculum at the elementary school level. When developing learning activities, teachers should strive to teach generalizable skills and concepts, to use time and financial resources efficiently, to engage students in highly experiential and conceptually transparent learning experiences and to complement the academic curriculum. In addition, teachers should evaluate, document and share their learning activities with colleagues. Together, elementary school and technology teachers can serve the technological literacy needs of young people as they prepare for life in a rapidly changing, highly competitive and technologically sophisticated society.

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Chapter 7 A New Paradigm for Schooling

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INTRODUCTION

Schools are not working for a large portion of our students who see education as a mindless and meaningless activity. The time for drastic change is here, calling for a new paradigm for schooling—a paradigm that discards the front-loading of theory followed by little if any application—and adopts a design-and-technology (D&T) approach wherein concepts and theory emerge from practice. Such an approach would change education irrevocably. Students would no longer ask, "Why do we have to learn this?" They would know why! Their practical problem–solving will create the need to know, and the knowledge they gain will have personal use and meaning. How different this method would be from the fragmented and decontextualized learning so often forced upon students.

In the D&T approach, teachers and students work collaboratively in learning and doing. As part of this approach, children perform as designers and developers, while teachers act as mentors and guides. Design thinking, fostered from kindergarten upward, includes investigating, creating, planning, making, testing, improving and evaluating. Design activity can foster group interaction and cooperation, perseverance, resourcefulness, divergence and self esteem—all fundamental preparation for life and work in the 21st century.

Activities representing the D&T approach of accessing and applying knowledge would include instances of:

- four- and five-year-olds using their knowledge in designing and building beds, rooms and homes for their teddy bears as the basis for further learning in math, science, reading and other subjects;
- children of different ages working with adults in the design and building of a concrete dragon for the school playground;

- young children designing and making a large wall map to a pending school activity for visitors;
- older students designing and making toys and other products for younger students;
- younger students telling older students what makes something a good toy or a good product for them;
- teams of students at several age levels working on a theatrical production, a video documentary or a magazine publication; and
- multi-age teams of students designing and developing traveling exhibits on developments in science and technology, costumes and cultures of the past, or their community—past, present, future.

The above activities, and a host of others, would nurture new ways of thinking and doing with increased valuing of knowledge and practice. Design and technology would deliver reflective thinking and doing to even the youngest of students. D&T would engage students in applying what they have learned to new circumstances, and in using those new settings for collecting data on their research and experience. Student reflection on this data would lead to making approximations, proposing solutions, iterating improvements and continuing the process by assessing how well all of these steps have worked. The D&T spiral would provide alternative ways of thinking, which makes failure a normal and respected part of learning and that supports students knowing more about their research and developments than anyone else, including the teacher.

INTEGRATED CURRICULUM

The new paradigm for schooling as implemented through D&T provides children with opportunities to learn and use knowledge in an integrated and supported fashion while working on real problems that have meaning for them. The D&T approach has been used to deliver instruction across the curriculum through integrated, realistic and developmentally appropriate experiences for children—experiences that are expansive and rich rather than restrictive and impoverished. The continuing separation of disciplines and the departmentalization of subjects promises to make the application and integration of learning across subject lines increasingly difficult. D&T must be able to provide a new vision of teaching and learning that can counteract the long-standing paradigm of specialization that has shaped—or more appropriately, misshaped—our schools.

There is growing evidence that the past practice of reducing curriculum and learning to their simplest, discrete parts is ineffective with students and teachers alike. Students can and do attend to activities over long periods of time if the activities are engaging. We need only witness children involved in selected play activities of their own choosing, such as using construction models and playing assimilation and computer games, for evidence of long-term attention and extended time-on-task.

Undergirding the desired involvement in complex planning and learning are new curricular and instructional strategies, such as scaffolding and fading as presented by Farnham-Diggory (1990), contextually appropriate curriculum and curriculum mapping described by English (1988) and thinking as a framework for curriculum and staff development from the ASCD (e.g., Marzano, et al., 1988) supported by organizing centers such as instructional planning tools developed by Hawthorne and Todd (1976).

The proposed new paradigm that engages students and teachers in both the acquisition and the application of knowledge through context-based problems exists and is already reshaping the nature of schooling in Great Britain. For more than 15 years, teachers at all levels have been using a problem–solving approach to DST (engineering). The success of that paradigm is evident in the new National Curriculum. In September 1990, "technology" became one of ten required subjects for all students aged 5-16. Initially, four major attainment targets (ATs) were established as educational goals for technology and included AT 1—Identifying needs and opportunities, AT 2—Generating a design, AT 3—Planning and making, and AT 4—Evaluating. Later, the attainment targets were reduced to two: AT1—Designing and AT2—Making. Within these general goals, whether two or four, many specific capabilities are identified to be developed in all students. The goals of D&T go beyond literacy to technological capability, which many believe to be a more realistic solution to the problems of technology in society. D&T begins early and follows a logical sequence of development throughout schooling.

The above attainment targets represent the D&T paradigm that shapes the learning experiences of all students and the instructional behavior of a growing number of teachers in Great Britain. There is no parallel in the United States at this time. There is, however, a growing interest in design and technology from outside the technology education profession.[1]

Elementary school teachers are generally prepared to teach across curricular lines through such integrated approaches as "reading across the curriculum." However, teachers generally and elementary school teachers specifically have had only modest experience in science and mathematics and little, if any, in technology. This lack of experience not only makes integrated teaching of these subjects difficult but also leaves teachers with inadequate constructs for understanding and teaching science and technology. Teachers, therefore, develop their own constructs that provide "functional explanations" of the real world, but these constructs may be closer to myth and magic than to being founded in the constructs of science. Constructs based in myth and magic will not only interfere with integrated science and technology but also will result in "poor" science as well.

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[1] *This interest is seen in the frameworks and benchmarks of Project 2061, a NSF-funded initiative of the American Association for the Advancement of Science (AAAS); the program announcements of the National Science Foundation (NSF); and the recent publication* Technology Education in the Classroom *by the National Center for the Improvement of Science Education. In Science For All Americans, Project 2061 directs a complete chapter to Technology and another complete chapter to "The Designed World." The NSF, in its announcements, describes technology education as a field of study strongly influenced by "design within constraints" thinking. The National Center's* Technology Education in the Classroom *gives major attention to the D&T approach as an essential part of technology education.*

Teachers may initially respond well to the idea of integrated learning, but if teachers are to *use* design and technology approaches for achieving that integration and at the same time *practice* "good" science, they must initially have supportive instructional materials. Lacking such materials, teachers tend to move away from new instructional approaches and return to more familiar teaching strategies and methods. These methods emerge from the teachers' vision or conception of the curriculum. To alter these concepts, teachers need curricular materials and activities that will provide a form of "scaffolding" that can help them (1) adopt new integrated approaches to teaching, (2) replace inadequate constructs, (3) reshape their conceptions of the school curriculum, and (4) acquire new skills in curriculum development. Provided such materials, teachers will be more likely to modify some of their own teaching practices and engage in curriculum development of materials that reflect the D&T paradigm.

INTERNATIONAL PERSPECTIVES ON ELEMENTARY DESIGN AND TECHNOLOGY

The requirement of D&T in the UK was based upon years of experience with teachers and students. Over the past two decades, the students who have had the D&T experience have proven to be a different type of graduate. It appears that these graduates, with their new skills, knowledge and attitudes, are more valuable to business and industry, particularly as the UK continues its progress in reentering the international marketplace.

A second and equally important rationale for implementing a design and technology approach is its effect on students. In some recent research on student assessment in the UK, it became apparent that students of all ages could perform at a level higher than expected. One finding of that research is of particular interest to those involved in educational change as it addresses the problem of increasing the involvement of young women in science and technology studies and careers. The research on assessment of the technology-related work of students found that, in selected instances, girls scored as well as and, in many cases, better than boys. The key factor of the success of girls in technology content and skills was one of *context*. If problems and activities emerged from contexts that made sense to the girls, they fared very well when compared to boys. If, however, learning and assessment activities were initiated without setting a context, girls did poorly relative to boys.

Unfortunately, science and technology activities are often initiated with little or no context and are evaluated with inappropriate testing methods. The growing experience in implementing D&T programs shows that the assumed lack of ability and interest of girls in science and technology may stem more from the collective näiveté in designing of instruction and assessment activities than from what young women can actually do in these fields of study. Understanding the role of "contexts of meaning" is essential to unleashing the scientific and technological talent of all students, girls and boys alike. Unleashing this talent will not only benefit the student but this country as well.

England, Scotland, Wales, Australia and parts of Canada are using the D&T approach and are giving serious attention to the concept of "progression." Progression deals with the cumulative acquisition of skills, knowledge and attitude as students move, in a temporal sense, through their schooling experiences. Progression goes beyond the concern for achieving of listed outcomes, objectives or standards and turns attention to how children develop socially and personally, as well as educationally. The potential of progression in practice is captured in the following observations made by Sellwood (1988).

> Accurate recording, assessment and evaluation procedures are essential to make sure that children achieve progression in learning. Consideration also needs to be given to the children's social and personal development, to ensure that boys and girls from various cultures and backgrounds are given suitable incentives to learn, and that the experience is equally stimulating for all the different groups. (p. 12)

Sellwood went on to identify three broad stages of a child's progression that fit within the design and problem-solving philosophy of education. These stages include structured play, guided discovery and project design (p. 13). His closing observations underscore the importance of progression to an investigative or problem-solving approach to learning and how learning is enhanced when children work in cooperative learning groups. All of these concepts warrant more attention and development.

D&T EDUCATION AND MATHEMATICS, SCIENCE AND TECHNOLOGY

As indicated earlier, the current models for integrating elementary school curricula clearly view reading as the focal point of instructional purpose. Such approaches build upon the current strengths of elementary school teachers. These same teachers tend to be much less comfortable about teaching science and mathematics and have seldom been prepared for teaching technology. The need for integrated mathematics, science, and technology education (MST; see chapter 3) is captured in the following statements from the *Benchmarks for Science Literacy* of Project 2061 (AAAS, 1993).

> Project 2061 promotes literacy in science, mathematics and technology in order to help people live interesting, responsible, and productive lives. In a culture increasingly pervaded by science, mathematics and technology, science literacy requires understandings and habits of mind that enable citizens to grasp what those enterprises are up to, to make some sense of how the natural and designed worlds work, to think critically and independently, to recognize and weigh alternative explanations of events and design trade-off, and to deal sensibly with problems that involve evidence, numbers, patterns logical arguments, and uncertainties (p. xi).

The utility found in linking mathematics, science, and technology helps students apply what they have learned to practical situations. Through that practice of application, students can learn even more. Thus, ESTE, when delivered through design and through problem-solving activities, can play a major role of enhancing the utility of science and math for students. The usefulness of what students learn is increased through concrete experiences as they (1) learn how to operate specific technological devices, (2) use that knowledge to improve those devices, and (3) integrate what they have learned as they design and develop new devices and artifacts. For example, students can be given the opportunity to use different types of water-lifting and pumping devices. After they have had a range of experiences, the students can use that knowledge to identify means of improving those devices. Based on those insights, the students might decide to develop new devices or use wind power or the power of flowing water to replace muscle power.

As students engage in scientific or technological activities, they must be able to describe those activities. Mathematics provides an essential means for that description. In some cases, this description may be possible through "direct" measurements of length, weight, temperature, time and other quantities. In other cases the description will call for the students to "derive" quantities such as area, velocity, acceleration and heat. All of these examples require the use of mathematics. In some instances, the math is little more than determining units and recording numbers. In other instances, the descriptions call for simple calculations, while still other instances demand more complex formulae and calculations.

Additionally, the utility of scientific and mathematical knowledge is increased as students learn how the concepts of science and math relate to practical instances. The use of Newton's ideas and theories in practice, as shown in the above example, would be significantly different than seeing those ideas and theories presented in a textbook or hearing them described by a teacher. Because of their active involvement, students will view other instances of "mass in motion" with an insight unlikely for more passive learners. Learning and applying scientific concepts represent important steps in the transfer of knowledge by students to new and unfamiliar instances.

There are two important instructional relationships between mathematics as it is integrated with science and technology. As indicated above, math provides the means to describe specific quantities related to selected instances of science and technology. In these cases, math helps quantify (tell how much) length, mass, heat and the like.

The second and more exciting relationship for instructional purposes is the practical and concrete forms that mathematics takes when put into use through science and technology activities. Normally, statistics represents an imposing set of ideas and processes that many students see as beyond their grasp. Integrated activities in science and technology allow for the introduction of statistics as one of the many ways to describe common practical activities. For example, students find it natural to combine the measured distances of several runs of a toy vehicle into one number. This new number, which represents and describes the average of all the runs, is a product of using simple statistics. Concrete activities can be quite powerful in helping students develop language related to and insights into statistics before they become involved in any statistical calculations. These activities provide the concrete and practical experiences from which students can be helped to build mathematical constructs and insights.

THE DESIGN AND PROBLEM-SOLVING PROCESS

"Problem solving" has a variety of meanings for different people in different subject areas. In science, it is known as the scientific method; in D&T it is recognized as the design loop, and in mathematics, it is seen as the setting of a task within a given context. For the purposes of technology education, problem solving is identified as a structured component within a general investigative approach to learning. It conforms to a defined methodology—the "design process" long recognized by designers, engineers and technologists.

The posing of open-ended questions and tasks represents the tools of a problem-solving methodology. The degree of open-endedness employed is critical to the required outcome. On one hand, questions or tasks can be narrowly focused and lead to the acquisition of specific knowledge. On the other hand, they can be broadly conceived and lead to wider and more interrelated understanding, usually within an appropriately chosen context.

The design-process model developed by Hutchinson (1995) is representative of the problem-solving approach being implemented in technology education programs internationally. The design process is often depicted as a "design loop" with different tasks to be accomplished. The tasks, too often seen as steps, should be considered as suggestive rather than prescriptive. In actual use, there will be marked differences in how individuals pursue a task and implement the process.

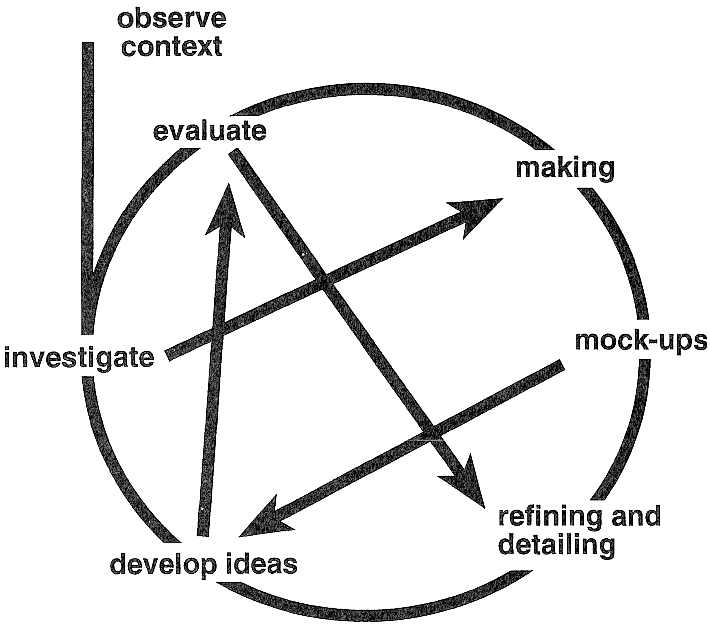

Figure 1 *The Design Process Model [The Design Loop].*

The process should be seen as iterative in its interaction between the active and reflective modes. The design process structures thinking at all levels and at each stage. During the process, there will always be the problem of the moment, as well as the overall problem or main objective. The development of creative-thinking and problem-solving skills is likely to result in pupils' "short-circuiting" the process by one or more stages and arriving at a sound and operable solution. Therefore, once students are familiar with the process, a slavish, stage-by-stage adherence to the model may impede learning. For example, many designers see the stages of testing and evaluation as the most appropriate starting points of the industrial design process. The design loop suggests that students may well enter the process at any of several points in the process, not the artificial starting point of identifying the problem to be solved.

AUTHENTIC ACTIVITIES, AUTHENTIC ASSESSMENT

Historically, the focus on technology education has been on the products or projects that students produced. In the United States, the products served as vehicles for helping students gain knowledge and skills related to the content of technology. The skills were focused largely on manipulative and analytic capabilities with little attention given to the skills of problem-solving. The reverse was largely the case in the UK. The products developed by students served as vehicles for helping them gain knowledge and skills in the process aspect of technology. The content of technology was generally limited to what was needed to complete the problem in which the student was engaged. Usually the focus on content or process was taken at the expense of the other, resulting in a lopsided approach to technology education. Recently, more attention has been given to the integration and balance of both the process and content of the field (Todd, 1988; Kimbell, et al., 1991).

Bringing these two aspects of the field into balance was intended to provide an involvement by students in the design and problem-solving process that was supported and enriched by an established and articulated technology knowledge base. The integration of the process and the content of technology placed considerable importance on how students were to be engaged in the learning and doing of technology. This involvement was characterized as a model of the interaction of mind and hand, illustrated in Figure 2 (Kimbell, et al., 1991).

The model identifies the essence of D&T as the interaction of mind and hand—inside and outside the head.

> [Design and technology] involves more than conceptual understanding—but is dependent upon it, and [design and

> technology) involves more than practical skill—but again is dependent upon it. In design and technology, ideas conceived in the mind need to be expressed in concrete form before they can be examined to see how useful they are. (Kimbell, et al., 1991, p. 20.)

Placing the interactive process at the heart of D&T relegates the products to a supporting role in that process. Concentrating on the thinking and decision-making processes that result in these products shifts more attention to the *why* and *how* pupils chose to do things than on what it was they chose to do. The pupil's thoughts and intentions become as important as the products that result from them. Students often believe, from the very start of an activity, that they have worked out a complete solution in their minds and will set out to translate that idea into final form. This belief seldom if ever is satisfactory, for they cannot mentally sort out all the issues and difficulties in the task, let alone reconcile them into a

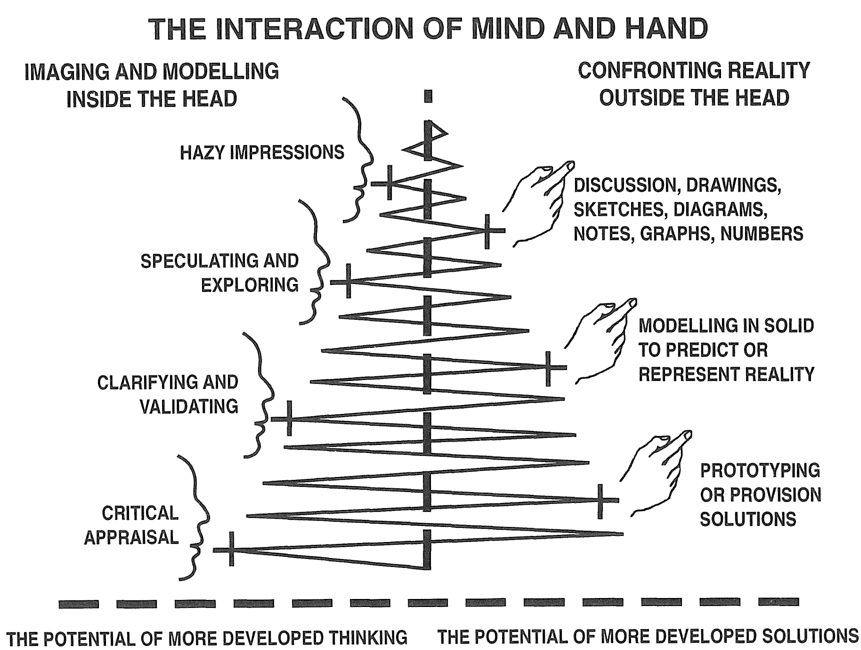

Figure 2 *The Interaction of Mind and Hand Model.*

successful solution. Basically, the students will actually have formed a hazy notion of what a solution is like. This notion can serve as a crucial starting point for them. However, it is only a starting point, and to enable the idea to develop, it is necessary to drag it out of the mind and express it in real form.

Modeling Solutions

But what of the other side of the equation—the different means of expressing ideas in various forms of reality? What forms do solutions take as an individual moves from initial representations of hazy ideas to more thoughtful and detailed solutions? Does the form of expression make any difference?

Kimbell and his team see expressing ideas as a necessary part of developing ideas, and see choosing the mode of expression as dependent on the design circumstances (Kimbell, et al., 1991). Part of the art of gaining capabilities in D&T is for students to develop a rich variety of modeling strategies through which their ideas can be appropriately expressed.

> Choosing the most appropriate forms of modeling involves thinking not only about what the idea is that needs to be expressed, but equally about how the modeling is supposed to help. If we wish to explore a basic concept for a new product (e.g. a new car radio volume control that adjusts the volume according to the ambient noise level) then, at this level of broad concept, discussion (verbal modeling) may be the best way to start. It is very quick and it helps people to get a grip on some of the big issues and difficulties that might need to be tackled. (Kimbell, et al., 1991, p. 21.)

Discussion has proven to be an essential means of representing and sharing ideas and potential solutions. This discussion is particularly true as students engage in collaborative learning with other students or with the teacher.

> But discussion alone does not allow us to get into the detail that would be required to evaluate how the noise sensing could best be achieved, let alone confront the details of

> electronic circuit design. Different types of modeling are needed that may be diagrammatic, or computer-simulated and that enable fine detail to be explored and resolved. As the electronics are being sorted out it will probably be necessary simultaneously to consider the styling and ergonomics of the developing product, and this needs a different form of modeling again, probably involving a range of graphic techniques and 3D models that fully represent the appearance and feel of the finished article. (Kimbell, et al., 1991, p. 21.)

Finished products, as the final form of a proposed solution, will in part represent what the student had in mind as the solution. However, the final prototype may be an arbitrary closure to the process of searching for the most effective answer. The prototype may be the best that a student can do in dragging the idea out of his or her head, or it may be a brief stop in the process with additional changes and modifications to follow. It may also be a detour down a wrong road, with the prototype representing a dead-end that will later be replaced by other physical models of more appropriate ideas and solutions.

All of the above possibilities illustrate how ideas may take form as students work through different levels of presenting progressively sophisticated solutions to a problem. Each level provides the students with a richer means of interacting with their evolving ideas and leads to potentially more developed ideas and more developed solutions.

> There is nothing particularly special about the "final" prototype, for the moment it exists it become the focus for yet further refinement and is therefore but another extension of modeling activity. In the commercial world, the endless progression of updated versions of existing products bears witness to the possibilities for refining and developing ideas. If scientific innovation (micro-chips, lasers, etc.) often provides the opportunity for product development, it is modeling that provides the dynamic driving force that carries the development forward from hazy ideas to refined and detailed working prototypes. (Kimbell, et al., 1991, p. 22.)

D&T, CHANGE AND STUDENTS

Perhaps the most important impact of ESTE is on the individual student. Historically, practical subjects have been among the few saving graces of schooling for many students, particularly those who find the standard classroom fare to be dull and of little consequence. At the elementary level, ESTE may provide this saving grace. Students who see little relevance in what they study often find the activities of technology education to be sensible and meaningful.

One such example involves a third-grade student named Sheldon. Sheldon is a bright young man often occupied with thoughts other than class activities and work assignments. He almost typifies the underachiever. As part of a thematic unit on apples, the class was introduced to design and problem-solving through creating a family of dolls. This activity involved preparing the apples so they could be carved as heads for their dolls and designing and making clothes and furniture for the figures. Sheldon brought back to school a completed outfit for his apple figure. When teased that he was lucky his mother was able to make clothes for him, Sheldon was quick to point out that the work was his and not his mother's. In a mixture of anger and pride, he demonstrated his skills in designing, laying out, cutting and assembling the parts into an outfit of appropriate size and proportion. Before long, Sheldon had become the consultant to others in the class as they worked on their outfits. Soon Sheldon became known as Shel-don' the designer.

Sheldon, or Shel-don', had moved from the perimeter of the learning process to stage center where he was not only "putting his knowledge to work" but was also helping to expand what was taking place in the classroom and school. He had become an active participant and contributor to the enterprise, an experience that is unfortunately too often missing for students.

A second example is significant in what it suggests for the level of thinking in which young students can engage. Early in the school year, a class in the UK that was being introduced to D&T was paid a visit by technology education specialists from Her Majesty's Inspectors (HMI), an agency whose primary purpose is to assess the quality of classroom teaching and learning. One of the HMI agents interacted with the students, much of the time sitting on the floor asking them well-phrased, penetrating questions. This agent was obviously someone who was good at this type of interaction and someone who enjoyed it.

The agent was interested in a working list on the chalkboard titled "Criteria." Upon questioning, a team of three students indicated that the criteria related to the problem they were doing on the design of a school playground. The agent then commented, "Hmmm, *criteria* is a pretty big word; what does it mean anyway?" One of the girls, not considered an outstanding student, rolled her eyes up and to the left in obvious searching manner, "Criteria, yeah, . . .those are the rules and judges we use to see if we are making good decisions." Later the HMI commented that in his years of visiting schools throughout Great Britain, this definition was as good a working definition of *criteria* that he had ever heard. And it came from a student whose abilities were in question.

D&T, Change and Teachers

The effects of the D&T approach on individual teachers takes several forms. Statements like the following frequently emerge when teachers are asked why they adopted this new subject and approach. "I was burned out, bored, ready for something different." "Teaching through a design and technology approach has made education exciting and worthwhile again." "Technology education has breathed life back into my professional career."

When asked what effect D&T has made on their teaching, teachers respond with such statements as: "using the design and technology approach has made it easier for us to collaborate on cross-curricular and cross-grade projects;" "the activities are more exciting for me and my students;" and "the parents love what we are doing and the excitement that their children show when they come home."

Finally, consider the personal observations made by two outstanding teachers—one a teacher of autistic students, the other a science support teacher. Kathy, the teacher of autistic students, observed, "this is the first year that I used the design technology approach with my class of autistic students, and the school counselor and I were amazed at the advances the students had made—the most improvement on the year-end tests ever." Bill the science support teacher, who had previously won a White House Award for Excellence in Teaching, commented, "I love science, and I have always enjoyed it, but after learning this design and technology approach, I'll never be able to teach science the same way again!"

D&T, Change and Classrooms

Visits to classrooms where the D&T approach was being used found students actively using a range of materials and resources. Working alone or in small groups, the students often were engaged in activities quite different from those of their classmates. Teachers were asked about this diversity of activity and the short attention span of students: doesn't all of this make the classroom unmanageable? The teachers admitted that they had to learn to deal with the noise and activity. They also grew to realize that what students were doing and the questions they were asking were often more important than what the teacher had to say. The teachers actually laugh at the idea that students have short attention spans. They know the idea that students will not stay engaged for extended periods of time is wrong. "A major problem we have is to get students to disengage and to move on to other things, even lunch and recess," they say.

D&T, Change and Schools

Change within a school or across a school system is far more difficult than implementing change in a few classrooms. Although some large-scale changes have been started by individual teachers working alone, change is an exception. Because of the barriers and problems of making changes, it is far more productive if, early in the process, interested teachers are supported and encouraged by administrators.

For the interested administrator, it is important to find a teacher or teachers who want to implement change, and then provide support to help in the change process. In the best circumstances, teachers and administrators come together in a common concern for improving what and how students learn.

In one instance, a supervisor of technology education found time to take on a project that fell outside his normal job duties. He was able to find two classroom teachers interested in learning more about hands-on DST activities and approaches. They were particularly interested in what these approaches might do for elementary school classes that were almost always a full-year behind grade level. The first year's efforts were demanding, frustrating, exciting and interesting. Limited to one day a week, the activities had only a modest effect on student performance. The Thursday activities were exciting for students, and the classes were always well attended. On closer examination, attendance on Thursdays was significantly up, an interesting departure from the absenteeism found on other days.

In the second year, the teachers and supervisor participated in more formal training in the preparing and implementing D&T activities. Over the next two years, the participating teachers gained new insights and skills in using the D&T approach. Positive results emerged as the teachers used those new skills. The most notable result was the success the teachers had in bringing their students back to-grade level in reading and writing—a result accomplished most successfully in classes where learning was shaped by the D&T approach.

There is a great deal that can be learned from D&T as a new paradigm for schooling. The foregoing presentation, observations, and projections can help move that learning process forward.

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Chapter 8 Implementing a National Program

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Society is in the midst of a technological explosion that will continue well into the 21st century. This will continue to alter our lives and our work styles. Examples include the use of laser scanners in supermarket check-out lanes, workers communicating to work instead of commuting to work and consumers considering a product in light of how it will impact the environment. Understandably parents, educators, and business and industry leaders want to prepare students for the technology they will encounter in the future.

One of the best methods for satisfying these demands is implementing the constructivist approach (Keiny, 1994, Robertson, 1994; to elementary school technology education (ESTE). Constructivism actively involves students in their learning, allowing them to develop critical problem-solving skills. Professionals in the field of science education (e.g., Gil-Perez & Carroscosa-Alis, 1994; McIntosh, 1994; Wilburg 1994) are beginning to embrace constructivism, as are educators in other fields. The benefits of constructivism are well known, but elementary school teachers still do not have all the necessary training and resources to implement a constructivist approach to ESTE. This is despite the fact that educators are on the front-line of imparting vital information and processes that affect the quality of life of future generations.

To help educators implement the constructivist approach in their curriculum, the Technology Student Association (TSA) developed a national program devoted exclusively to meeting the technology literacy needs of elementary school children. It is the first technological literacy program in the United States suitable for elementary school teachers to implement with students of all abilities. This fun, exciting program is called the "Great Technology Adventure."

ESTE IN THE ELEMENTARY PROGRAM

There are numerous ESTE reform initiatives being implemented in the U.S. at local, state, and national levels. The United States is not alone in the search for delivery methods to move students toward building their own knowledge. "The constructivist classroom style is embraced through the United Kingdom's establishment of their 1989 national curriculum, specifically mandating contextual based, hands-on delivery" (Her Majesty's Inspectorate, 1991, p. 4). It is certain that if elementary school educators effectively implement constructivist methodologies via thematic ESTE units, the curriculum will become enriched and the students can become thoroughly enthusiastic about becoming life-long learners.

Constructivism in ESTE

ESTE naturally lends itself to constructivism. Although traditional approaches such as discovery and reception learning have been beneficial to some students, constructivism is intended to allow all learners to construct their own bases for learning and understanding. In the constructivist classroom, students are actively involved in learning via engagement, interaction, reflection and construction. The outcome of constructivism is that students can achieve traditional elementary school objectives while engaged in ESTE activities. The opposite is also true, as technology learning can take place when students are engaged in other school studies. There are a number of educators who have addressed these topics in their research.

Constructivist Research

Dunn and Larson

Dunn and Larson advocate that teachers introduce the design process to bring constructivism in the classroom (1990, p. 1). The design process brings learning to the student in a contextual format. Students are actively engaged in exploring challenges and opportunities, as well as human wants and needs. Dunn and Larson used the *Life Span Cognitive Development*, performed by Rebok in the late 1980s, to emphasize the need for this type of instruction.

> Through their actions, or more precisely, interactions with the world, humans construct their own experience and knowledge. Philosophically, that is a constructivist view; it contrasts with mechanistic views, which consider all knowledge to be copied directly from external experience (Dunn and Larson, 1990, p. 12).

Dunn and Larson also provide a framework that can integrate ESTE with other curricular areas. "The strength of this framework comes from the natural connection that can be shown between curriculum areas, the design challenge, and the inclusion of technical knowledge and processes skills" (Dunn and Larson, 1990, p. 27). Teachers are empowered to recognize relationships between the curriculum and the child's interests and needs. The constructivist classroom provides a vehicle for the delivery of meaningful and connected experiences at all levels. Problem-solving in ESTE provides new and unique learning experiences that are readily adaptable to varied learning styles.

Brooks and Brooks

The 1993 ASCD publication *The Case For Constructivist Classrooms* by Brooks and Brooks is the most in-depth and comprehensive popular publication on the constructivist approach. "Constructivism is not a theory about teaching. It's a theory about knowledge and learning" (p. 7). This approach genuinely respects the learning styles and process of students. The constructivist teacher values students' points of view, creating a structure for teaching based on primary basic concepts. From these concepts evolve powerful thematic units that can connect student learning across traditional subject-matter areas.

The powerful impact of this approach is yet to be fully realized in education. Brooks and Brooks note that "for many educators, becoming a constructivist teacher requires a paradigm shift" (p. 25). This shift can only occur when the teacher internalizes his or her own constructivist meanings and application to curriculum content and delivery system.

Brooks and Brooks' publication provides five basic principles of a constructivist classroom: (1) posing problems of emerging relevance to learners, (2) structuring learning around broad themes and providing primary concepts, (3) seeking and valuing the learners' points of view, (4) adapting curriculum to address student needs and (5) assessing student learning in the context of the process in which students are being taught.

Todd and Hutchinson

"Design and Technology is about putting knowledge to work" (Todd & Hutchinson, 1991, p. 7). Todd and Hutchinson propose that quality—not quantity—of knowledge is critical. They believe that education has underestimated students' abilities, particularly when using and showing their abilities. Students are often asked to design and create 'projects.'

Unfortunately, the majority of these projects are disconnected from other learning and do not usually have a connection to future learning. "Putting knowledge to work is facilitated if the people using that knowledge have the need and opportunity to discuss what they are trying to accomplish and the problems they are encountering in their efforts" (Todd and Hutchinson, 1991, p. 7). Todd discusses design technology in this yearbook in chapter 6.

Incorporating Constructivism in the Classroom

The constructivist approaches outlined in current research indicate that the strongest emphasis of implementation is taking place at the elementary school level. However, there is also a sense in constructivist literature that educators are just beginning to scratch the surface of change. Brooks and Brooks (1993) state that most teachers agree with the goals of constructivism but have a difficult time practicing it. There is a need to provide programs that encourage collaborative practices among teachers, so they can begin to construct their own concepts regarding the implementation of constructivism.

Large-scale change can begin with teacher education (see chapter 10), if a true transition is to take place in the future. Another arena is staff development and ongoing support (see chapter 11). Achieving constructivist outcomes via ESTE is the basis for the development and implementation of the Great Technology Adventure program.

THE GREAT TECHNOLOGY ADVENTURE

The Technology Student Association (TSA) received numerous requests from principals, superintendents and school board members for suggestions on how to integrate ESTE into the curriculum. Teachers expressed a desire to become more informed about ESTE and to learn more about the value it can add to their classrooms and the benefits it can provide their students. In response, the Great Technology Adventure program, an interdisciplinary technology literacy program for students in grades K-6, was introduced by TSA in 1992.

The Great Technology Adventure is a school-wide membership program designed to help elementary school educators transcend the physical hardware of instructional technology and expose their students to ESTE problem-solving. The development of analytical thinking is also emphasized. Every student in each member school may participate in activities and challenges. Because this program is co-curricular, it adapts easily to the daily classroom activities and the existing curriculum.

Teachers who use this process in their standard curricula facilitate student learning through the technological process: 1) identifying problems, human wants and needs, or opportunities; 2) analyzing technology impacts; 3) investigating possible solutions; 4) selecting a viable solution; 5) prototyping the solution; and 6) testing and evaluating a solution and communicating it to others. Interesting topics and contexts excite students, reward technologically sound thinking and encourage teachers to look for technology-related applications in subjects they are already teaching. The program takes the enthusiasm, imagination and energy present in elementary schools and creates an early technology pipeline intended to carry students successfully into the future. This program can be a vehicle for educators to expand classwork beyond instructional technology and expose their students to the value of design and technology processes and problem solving in order to develop analytical thinking skills and let students become lifelong learners.

Program components

The elementary–school program kit includes teacher activity guides, a technology poster, essay and robot building challenges, technology team challenges, a children's technology newsletter and on-line networking capabilities via the Internet. These materials are also combined with an awards and recognition program intended to build a national ESTE community.

The membership materials walk classroom teachers through the technological problem–solving process by providing sample activity challenges, individual student-project log sheets and an activity assessment form. Participating in the national challenges is another way for students to engage in friendly competition within the school and throughout the nation.

The Great Technology Adventure provides a vehicle to implement technology education on a K-12 continuum that achieves the following outcomes.

- Students will become familiar with how people create, use and control technology.
- Students will have the ability to apply related knowledge in math, English/language arts, social studies, science, health and fine arts in solving problems associated with design and technology.
- Students will have the ability to use tools and materials to explore personal interests with technology.
- Students will build their self-confidence through the use of technology.

Program implementation

The Great Technology Adventure is designed to be a companion to the subjects of the traditional curriculum. This can make ESTE an integral part of every school day. The program is based on thematic areas that interest the student and include rewards for sound thinking. Teachers are encouraged to find technology-related applications in what they are already teaching.

The successful delivery of a whole-school program is significantly enhanced when specific teachers are designated to be the lead instructors to implement the program. Experience during the pilot phase of the program indicated that the most successful approach is to develop a team that includes representation from as many-grade levels as possible. Lead teachers will be the first to use the open-ended, thematic design–brief activities and may offer other teachers suggestions to make activities more applicable to a particular class or scenario.

Often, teachers base many of their technology lessons and contextual activities on provided design briefs. Once teachers are comfortable with the design-brief process, students should be encouraged to write their own design briefs, basing them on what they are studying or on current events in the news and community.

Employing the Design Process

As these contextual design briefs are used, students must document their thinking and creating process through a technology log. This journal-keeping process provides a link between designing and prototyping during the development of well–thought–out solutions to problems, and allows students to learn and document their planning. Sketches of possible solutions are analyzed to determine what is possible and how different components of a solution fit together. Students should also generate a final sketch with labels accurately depicting how different ideas are combined and improved to create the best solution.

After thinking through a design solution, students are ready to test their ideas. Depending upon availability, resources may include such things as "found materials" (e.g., scrap wood, spools, cardboard, glue and paper fasteners), commercially available manipulatives and constructive materials, and CD-ROMs. Applying the technology process is not dependent upon any certain tool or resource. It is dependent upon applying available tools and resources to meet the defined criteria in the design brief challenge and context. As students formulate solutions, they begin to understand the principles behind how and why tools and materials work, and learn to refine their solutions based on these properties.

Communicating the final solution to peers gives students opportunities to practice public speaking and to learn to critique others constructively and accept criticism themselves. As each group in the class presents different solutions to the same problem, students become open to thinking creatively and seeing that there is typically more than one solution to a problem.

Materials Provided with Membership

Listed below are the sections of the program's membership kit. Teacher feedback is used for on-going restructuring of the program materials and future professional development opportunities. TSA has also received valuable input and support from an advisory panel of representatives of business, industry and the general community.

Although many materials are included in the kit, each member school must be willing to allocate financial resources for the acquisition of simple technology tools and materials for classroom instruction. In addition, time and physical resources must be available to foster teacher growth and development.

Introduction (Section 1). The Great Technology Adventure uses design and technology (DST) to facilitate the integration of ESTE into the existing curriculum. This hands-on approach to ESTE allows students to see the outcome of a solution and provides feedback and refinement. Section 1 includes an overview of the program and of ESTE.

Publicity (Section 2). Parental, community and media awareness are critical to the success of the program. While traditional educational programs like mathematics, science, language arts, and social studies are well understood, ESTE is not. Informing the public of ESTE is supported in this section with ideas and strategies for building support among parents, community and the media.

Implementation (Section 3). This program is designed to work in elementary schools regardless of size, class numbers or subject matter. Its implementation is through existing elementary school curricula, and its goal is to teach technological skills, including problem solving, critical thinking and creative solutions. Computers, video cameras and other "high tech" equipment are not necessary for implementing the activities, although they may be used for carrying out a solution in some cases. This section of the kit outlines steps for implementing the program and includes master transparencies with a teacher guide to help introduce technology.

Career Awareness (Section 4). Technology has had a tremendous impact on the world of work. By cultivating awareness of technology and careers, teachers can help students clearly see the relevance of the skills they are learning in relationship to the real world. Students become enthusiastic and creative when classroom activities are presented in light of their communities, their families and themselves. This section of the kit includes a complete career-resource teacher guide and transparency master set.

Simple Machines (Section 5). Simple machines are the basis for essentially all mechanical designs. We are often unaware of how we use simple machines in our everyday life because they are so much a part of what we do. Connecting simple machines concepts to reality happens through the hands-on application of their principles. Section 5 of the kit contains several different simple machines resources.

Curricular Integration. (Section 6). Integrating ESTE activities is accomplished through an understanding of the purpose of the activities, the resources of technology and how they are applied, and the willingness to try an activity to learn the process. The kit includes helpful aids for writing and integrating teacher-created design briefs, as well as a set of design briefs based on thematic units. Sample technology logs and portfolio assessment ideas are included as well.

National Challenges (Section 7). The program's national challenges are designed to provide a forum for teamwork, as well as providing for individual student accomplishments. The national challenges have the potential to bring recognition (local and/or national) to individual schools and can be used as an avenue to promote school participation in the integration of ESTE. Also included in this section are current topics and criteria for national challenges and forms to submit entries.

Communication (Section 8). Communication among member schools is an important part of the program. Section 8 provides an avenue for learning about activities and ideas in other schools around the country and fostering innovation in each school. The kit also contains a list of resources, literature and references to enhance a teacher's use of the program. Schools also receive periodical newsletters for students and teachers.

Affiliation

Schools pay a yearly affiliation fee for membership in the program. All teachers within the school have access to all materials, which may be copied and used on an unlimited basis within the school. Each school receives two copies of the kit of materials. Student and teacher newsletters are supplied during the school year and may be copied for distribution within the school.

Affiliation provides additional benefits. Teacher preparation and professional development opportunities for teachers emphasize student learning through the use of the DST process. State departments of education, higher education institutions and district instructional leaders provide limited access to professional development opportunities for teachers. Teachers currently involved with the program are encouraged to network with each other via a pen-pal classroom system and interact with others via the World Wide Web. The national network of schools has reached over 300 in the third year of the program. As more schools join, this communication will undoubtedly increase, especially through electronic avenues such as the Internet.

THE PROGRAM IN DELAWARE AS A CASE

Like most other states in the U.S., Delaware has been undergoing major education reform for the past few years. National standards have been released by many of the major academic organizations, and state departments of education have tried to implement these standards to best meet student needs. At the elementary school level, educators have been charged with the monumental task of teaching more in the same amount of teaching time. Implementation of the Great Technology Adventure program has been found to assist elementary school teachers in better delivering and meeting their necessary educational objectives, as well as beginning to address the technological literacy of students.

Most of the first 25 schools in Delaware that have participated in the program have found the materials and activities to constitute an exciting, fun program for children. Importantly, students who are limited in their English proficiency have had success with this integrated and interdisciplinary delivery system.

Using literature and theme bases for hands-on contextual challenges provides a vehicle for these Delaware elementary school teachers to build the self-confidence and knowledge of their students. The thematic units have allowed teachers to better use authentic assessment processes and to have students assess their progress individually and in small groups. The use of communication skills is also a primary goal in describing solutions to their peers.

In Delaware, administrators involved in the program have encouraged their teachers to incorporate this design and technology process across-grade levels and have found many teachers working together and sharing their ideas and experiences.

For example, Linda Rogers, principal of Stokes Elementary School in the Caesar Rodney School District, emphasized the importance of differentiating between quality ESTE activities and instruction and mere hands-on experiences and computers. She says that "the design and technology education process brings the real world into the classroom." Gary Bell, Supervisor of Instruction for the Brandywine School District, describes the program as:

> a teacher resource as we introduce technology education into our elementary schools. As with any new educational venture, teachers look for resources to provide examples of successful design briefs, suggestions for implementation, and a phone number to call for assistance in locating practitioners. TSA continues to provide this teacher support with increased distribution of resources and serves as a clearing house for exchange of contextual problem solving activities, developed by educators, to implement technology education in elementary school classes.

Joanne Freed, a second-grade teacher at Stokes Elementary School states, "design briefs are engaging students in problem-solving, not just stand-alone activities. Students are learning in context, which in turn brings relevancy to both instruction and learning. This process gives the students the ability to reinforce and apply language, math, science and social skills!" One of Freed's second-graders, Angie Brenwalt, was excited by the ability to "be creative and think up my own ideas. There are lots of problems that have lots of solutions. It's hard choosing which solutions to use. Some solutions don't work, so you have to keep trying different ideas!"

CONCLUSION

TSA's Great Technology Adventure program is based on a vision of how teachers should teach and how and what students can learn in elementary schools. This is based on the following principles:

1. Teaching focuses on a process of design under constraint.
2. ESTE is integrated into all other curriculum areas through the design and technology process.
3. There is a strong and validated framework for most curricular areas based on national directives, such as the SCANS competencies and national subject-matter standards.
4. Technology education prepares students for real life through individual and group problem-solving activities, cooperative learning and the development of critical and innovative thinking.
5. Students have the opportunity to learn, apply, and take advantage of instructional–technology tools (hardware, software, equipment), as well as "found materials" resources.

This program provides the support and resources necessary to make ESTE an integral part of any teacher's program. It can be an exciting vehicle for integrating analytical skills into the existing elementary curriculum in a way that is meaningful for everyone. It requires no special equipment—just interested teachers and the natural enthusiasm of children. While instructional–technology software, video cameras and other "high-tech" equipment are all components of today's technological society, the ability to design and solve real world challenges is the foundation for teaching technology. The workplace of tomorrow is dependent upon the problem-solving abilities of today's youth. It is part of our mandate as educators to provide quality education to ensure that our children have the necessary tools and foundation for making critical decisions in this rapidly changing world.

While these outcomes may be achieved using many creative methods, the infusion of an ESTE approach provides a comprehensive and focused process for either an individual teacher or an entire elementary school. Being part of an established technology network is an exciting way for all schools to become part of a national technology education community.

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Chapter 9 An Articulated Whole-School Approach

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This chapter will present the development and status of the internationally recognized, dynamic, unique, and articulated K-12 technology education program of the Center for Applied Learning in Ten Sleep, Wyoming. This program is internationally recognized in that it received the International Technology Education Association Program Excellence Award in 1994. It is dynamic in the sense that the curriculum and the facility are constantly evolving. It is unique in that students from kindergarten through twelfth–grade share the same technology facility are taught in a variety of instructional methods, including peer tutoring. It is articulated, by design, so that instruction builds on what the students have learned from the students during the year(s) before.

Teachers at the rural Ten Sleep School have implemented progressive methods of teaching and learning in order to address a number of influences that are transforming our schools and our society. One method is the use of elementary school technology education (ESTE) as a vehicle for applied learning. Contemporary learning theories and innovative instructional strategies is among the methods being employed.

The Community

The community of Ten Sleep, population 390, is located in a scenic valley in north-central Wyoming. Ten Sleep is an agricultural community on the western side of the spectacular Big Horn Mountains. The local economy is dependent primarily on cattle and sheep ranching, with some employment in the mineral extraction and manufacturing industries.

In the past, Ten Sleep was a favorite Native American camping spot because it had plentiful fishing in nearby rivers. Since the spot was ten nights' sleep between the trading post at Fort Laramie and the hunting grounds in what is today Yellowstone National Park, it was called "Ten Sleep."

Washakie County School District #2 serves a large, sparsely populated geographical area of over 1000 square miles. Students living as far as 40 miles away are transported to the school. The district maintains a K-6 elementary school, a 7-8 middle school and a 9-12 high school all under the same roof. The total enrollment of the Ten Sleep School was 144 students when the Center for Applied Learning (CAL) was first developed in 1992.

DEVELOPMENT OF THE CENTER FOR APPLIED LEARNING

The CAL began as a vision of the high–school industrial and technology education teacher in 1990. The school's principal informed the Ten Sleep faculty of the availability of funding through a Wyoming Innovative Trust Fund. This money, accumulated during the energy boom of the 1980s, was earmarked for the improvement of education in the state through innovative programs. Faculty members were encouraged to apply for these competitive funds.

Ten Sleep's industrial technology teacher had been at the school for three years. He was familiar with technology education philosophy and practices and had been looking for a way to renovate his program. He had visited several well-known high school programs in the region. Based on these observations, he approached his principal and superintendent with an idea for a technology lab that would be the hub of the school curriculum. It would be a facility for all of the school's children, kindergartners to high–school seniors. It would enhance the existing curriculum and provide a more relevant education for the 1990s. The principal liked his ideas, and together they set about the task of writing several funding proposals. The result of their efforts was a three-year Wyoming Innovative Trust Fund grant for a total of $143,000.

Actually, it wasn't quite that simple. The process also involved convincing the faculty and the school board of the value of the concept. Some board members questioned why the school needed "all this technology." After all, this area was just a small rural farming and ranching community, and there weren't any high-tech industries in the area. But eventually, the board endorsed the proposal.

The elementary school teachers at Ten Sleep were the most supportive of the concept from the start. This support was probably due to the fact that the elementary school curriculum tends to be more integrated than the high school curriculum. Many of the school's elementary classrooms already had "learning centers" for exploring topics like writing, listening, reading, science, or art.

Teams of teachers and school board members were sent to visit schools with state-of-the-art technology laboratories. After much discussion and several visit, the faculty decided to purchase a Creative Learning Systems (CLS) "Technology Lab 2000." (*Technology Lab 2000*™ is a registered trademark of Creative Learning Systems, Inc. This commercial modular laboratory will hereafter be referred to as the "Lab 2000," and is just one component of the Center for Applied Learning.) The advantages and disadvantages of commercial modular or "packaged" laboratories have been debated widely (Daugherty & Foster, 1996; Petrina, 1994). Too many "canned" labs are limited in scope, vision and adaptability. Many labs are also more oriented toward student management systems (Thode & Thode, 1993; Zuga & Bjorkquist, 1989) than toward students. However, the Lab 2000 provided the most flexible platform from which to build the Center for Applied Learning.

The Facility

It was essential to integrate the CAL with the existing industrial technology facilities and program. Before renovation, the facilities included a wood shop, finishing room, welding shop, automotives area and open work space. The wood shop was converted into the Lab 2000 with a classroom, small reference library, photography and laser-holography darkroom, and an open work space. A general-purpose fabricating area, where some of the materials-processing tools were relocated, was created at the expense of the auto area. An existing classroom area was modified to accommodate digital-video editing, multimedia production and student seating-presentation areas. The welding facility was slightly modified to allow for more research and design work in an open-space area. Access was provided from the Lab 2000 to the traditional "shop" facilities, with sound-proof glass windows placed in the adjoining wall to provide an increased sense of "connectedness."

The resulting learning-teaching environment of the CAL was representative of a state-of-the-art design, fabrication and testing facility, comprised of two primary spaces: the Lab 2000 area and a general-purpose fabricating space. Specialty labs clustered within the CAL space included a digital audio and video studio, animation and multimedia production, presentation and teleconferencing capabilities. *Adjacent* to the Lab 2000 was the materials fabrication laboratory where projects using a variety of composite, polymer, wood and other materials were brought to life. More recently, a student-built dynamic flight simulator has been added to this space.

Curriculum Development

During the first semester of operation, Spring 1992, the teacher and his students learned about the hardware and software of the Lab 2000 together. During this time, the teacher continued to design the curriculum that would integrate the varied learning experiences and labs into a comprehensive environment.

This curriculum development required research on philosophical issues, such as instructional strategies, methodology and curriculum design, as well as practical issues such as lab organization and the structure and sequencing of learning experiences. A technology education professor from Montana State University acted as a consultant for this phase of the project and assisted with program articulation. Several resources were consulted, including Foreman and Etchison (1991), Braukmann and Pedras (1990), Denton (1990), Korwin and Jones (1990), Clark (1989), and Zuga and Bjorkquist (1989). Consultations with other technology teachers, such as Brad and Terry Thode of Idaho, and careful study of other outstanding programs were also conducted. Lab and curriculum development continues to evolve and be influenced by current practice and research, such as Hill (1996), Thode (1996), Gokhale (1995), Thode and Thode (1993) and Kirkwood (1992).

Curricular Components

The evolving curriculum combined features of the "technology modules" with the Lab 2000's more traditional materials-based laboratory activities. For example, in the Lab 2000, secondary students would test the strength of composite materials on the structural-strength analyzer, which would output a plotted graph of time vs. force, while they would also test the strength of their fabricated welds on conventional testing equipment. Elementary and middle school students would design and construct different structures made of paper, such as cylinders or honeycomb, that would also be tested on the structural-strength analyzer. Many secondary students were involved in designing and building specialized apparatuses for this new curriculum. The CAL also provided experiences in reading, art, writing, music, research, problem-solving and weather monitoring for elementary school students. A copy of the curriculum guide discussed in this chapter is available for the cost of reproduction. Contact Mr. Chip Miller, Center for Applied Learning, Ten Sleep School, PO Box 105, Ten Sleep, WY 82442.

Boxed, Modular Activities

One of the most creative and beneficial aspects of the Ten Sleep ESTE program was the development of boxed, modular technology activities. The material from each of these self-contained learning centers was stored in a box that elementary school teachers could check out for use in the regular classroom. This allowed ESTE to be experienced by children in their classrooms, not in a specialized lab. Thus, students have come to view technology independently of the computers in the lab. The computers, in turn, became tools for learning rather than objects of study.

Fifty boxed, modular activities were developed by the technology teacher during the first two years of the CAL. Some of these activities were original in design, while others were adapted from existing activities. Each box contained an information sheet about that technological area for the teacher, an activity for the class, and all materials necessary for demonstrations and student projects. The elementary school teachers found these boxed activities to be extremely valuable and to greatly enhance their regular curricula. Below is a list of some of the topics of the boxed activities.

- Flowcharts.
- Exponential change.
- Precision measurement: Using the micrometer.
- CD-ROM: how it works.
- CAD and the coordinate system.
- Machine dissection.
- Solar electricity.
- Solar collector.
- Thermal expansion of solids.
- Introduction to lasers.
- Hot air balloons.
- Mass production: The cookie factory.
- Problem solving: The fire mouse.

Daily Schedule

Secondary classes scheduled in the CAL included *Explorations in Technology, Computer Graphics, Energy and Power, Materials, and Multimedia*. Several students were also enrolled in independent courses to explore problems of personal interest or to assist with designing and constructing specialized apparatuses supporting the new elementary school curriculum. In addition to the regularly scheduled secondary classes, an "open" scheduling policy was permitted for elementary classes. Thus, each elementary class had the opportunity to participate in the tech lab at least one day per week. Elementary classes frequently came to the CAL during a period when a secondary class was meeting.

Another aspects of the CAL was the involvement of parent volunteers. Quite often students were able to demonstrate advanced computer software applications to their parents! Peer tutoring was another key element in the evolving curriculum. For example, fourth-grade students who had already learned how to program the robotics arm would occasionally help instruct second-grade students.

The Ten Sleep technology teacher decided to test the Ten Sleep ESTE program with the most difficult students of all—other teachers. He offered workshops for elementary school teachers for high school teachers in the CAL during each of the summers of 1992, 1993, and 1994. Feedback from the participants and from participants in later workshops continues to shape the program at Ten Sleep. Summer institutes are an ongoing priority of the program.

Developing an Articulated Technology Education Program

From the beginning, the plan for the CAL involved a facility that provided for meaningful, relevant student experiences and opportunities for discovery from kindergarten through the twelfth-grade. Thus, the program had to have *vertical articulation*. The program also needed *horizontal articulation* (a more thorough treatment of curriculum articulation is provided in chapter 3 p. 86). Teachers at each-grade level and in each subject area were consulted in an attempt to identify common themes and strands throughout the school curriculum. Ten Sleep School District curriculum documents were cross-referenced and paired with ESTE objectives.

Carefully designed learning experiences also needed to reflect children's developmental stages, as well as provide a foundation for more in-depth exploration in subsequent years (Dewey, 1938;

Gardner, 1991). Three principles guided the development of this curriculum: (1) the processes of problem-solving and design should be emphasized over their products, (2) students should have responsibility and initiative for learning and (3) students should be allowed to construct their own understandings from relevant experiences.

APPLYING CONSTRUCTIVIST THEORY

In the preceding chapter, Steven Barbato discussed constructivist theory as it relates to ESTE. One important consideration is the application of this theory to an articulated, K-12 program of technology education.

In a constructivist classroom, learning is driven more by student inquiry than by teacher assignments. In the Ten Sleep curriculum, the students are allowed to construct their own meanings and organizational relationships (Brooks & Brooks, 1993). Students learn about the broader notions and interrelatedness of technologies and were not bound by the confines of artificially created content organizers (i.e., communications, construction, manufacturing and transportation). It was fascinating to observe the relationships that students constructed amongst things they learned in their technological endeavors.

Constructivist Theory

As Barbato notes in chapter 8, the term *constructivist theory* is derived from the belief that people learn by internally constructing their own understandings by assimilating new information and experiences into their existing knowledge and experience. Since each individual has had different life experiences, each must interpret new information and experiences in light of his or her own background and personal experiences. Many cognitive psychologists argue that this assimilation is the only way real learning and understanding occurs.

While the name of the theory has nothing to do with actually constructing physical projects, it is true that many young children are better able to understand ideas (i.e., to construct meaning) when they are allowed to physically manipulate objects (Rosser, 1978). Indeed, manipulatives are an important part of constructivist theory. In this sense, constructivism is supported by Piaget's (e.g., 1969) learning theory: ESTE provides solid support for children's development (Dahl, 1979).

Constructivist theory has roots in the writings of John Dewey, who inspired the early industrial arts movement. Dewey (1938) advocated a student-centered approach to learning and teaching. Recognizing that children are naturally curious and exuberant, Dewey suggested that teachers should allow for exploration and inquiry and stimulate curiosity. Memorizing trivial information, he noted, is not sufficient preparation for children, nor does it assist them in learning to solve real problems.

Constructivists hold that real understanding occurs through the transformation of new information, which leads to the emergence of new cognitive structures (Gardner, 1991). These transformations are the desired result of carefully constructed learning experiences which cannot be mandated or legislated. They cannot be prevented either, although poor teaching practices may inhibit or retard their occurrence.

One example of this naturally occurring process is the infant who stares at the block dangling over her crib for the first three months of her life, then is finally able to reach out and touch or grasp the block with her newly acquired skills. This contact, touching and turning of the block will affect her understandings of the block.

It has long been known that students learn better from "doing" technology rather than just reading about it or observing it (Gunther, 1931). While it is true that some technological concepts cannot feasibly be experienced by students in school (e.g., nuclear fusion), most concepts and principles can be directly explored or simulated by students. ESTE, like constructivism, is predicated on direct student involvement with exploration and manipulation of the subject matter.

Another very important advantage of constructivist classroom practice is the excitement and enthusiasm it generates. These emotions are evident in both teachers and students. Research has established that enthusiasm is one of the most important characteristics of effective teachers ("Enthusiasm," 1981).

Finally, constructivist teachers learn with and from their students. The teacher needn't be at the center of everything in the classroom. Like good ESTE programs that utilize design briefs or similar learning tools, constructivism casts the teacher into a new role as a facilitator who explores with students. This new role also requires different assessment techniques.

Assessment

We are all accustomed to using evaluative words such as "no," "good," "right" and "wrong." Responses such as these encourage students to become dependent on the teacher and to pursue pleasing the teacher rather then learning. Students may even cut short their own exploration due to some external teacher response. Thus, it is imperative that teachers in this new role learn to use non-judgmental feedback techniques. This helps learners to discover for themselves important concepts and relationships by responding

> to students' assertions with plausible contradictions, to students' requests for assistance with requests for explanations of their thinking to date, and to students' arguments with responses . . . that place the responsibility on students for assessing the efficacy of their own efforts, and make pleasing the teacher far less important (Brooks & Brooks, 1993, p. 95).

Refining the Ten Sleep Curriculum

When the ESTE curriculum at Ten Sleep was being written, instructors knew that the focus had to be on teaching major concepts at increasingly greater levels of sophistication rather than on just "watering down" middle school or high school experiences. Notions of control technology, for example, began as early as Kindergarten or first grade with design and problem-solving experiences with commercially available kits for making motorized models, followed by simple pick-and-place robotics arm activities in the second grade, which lead to greater precision and expectations in the fourth and seventh grades, and culminated with sophisticated computer-aided design and manufacturing at the high school level. Not every concept was introduced into every-grade level. Indeed, most were spiraled through the-grades on an every-other-year or every-third-year basis, as this control technology example would indicate.

Similarly, ESTE activities in the first and second grades provided students with opportunities in reading and writing. Fourth grade students are introduced to the world of telecommunications. This is followed by an introduction to graphic design, layout and the production of notepads in the fifth grade. Students explore desktop publishing in the eighth grade and Internet, fax, and teleconferencing in the ninth grade. High school students focus on simulated satellite communications and multimedia development.

From Lab 2000 to Complete Technology Education Facility

The curriculum continues to evolve with resulting student and teacher growth, which continually drives the dynamics of the environment. The canned or "modular" units of instruction that arrived with the Lab 2000, and a number of the early teacher-developed technology learning activities are no longer used as stand-alone units of instruction. They are used where appropriate to introduce new concepts prior to immediate application. The instructional environment is custom-tailored to the learner and is expected to grow with the learner, thus providing an endless web of opportunity (Brooks & Brooks, 1993). It is a good example of the curriculum (i.e. student needs) driving the facility (Thode & Thode, 1993). This facility is dynamic and is designed to allow for changing needs.

The ESTE program is becoming increasingly involved with the elementary school curriculum as teachers and parent volunteers gain greater comfort with the tools available in the facility. Activities and processes previously thought to be challenging to middle and high school students are now gaining acceptance at the elementary school level. Third- and fourth-grade students and teachers integrate digital and traditional photography, darkroom techniques, computer-generated animation and simple-machine construction into the curriculum. These same students contribute to additional projects in the CAL as they team up with high-school students on large projects, such as the design and construction of a high-mileage vehicle or, more recently, on the design and construction of a dynamic flight-orbiter simulator.

The Ten Sleep School and community are committed to providing a dynamic school environment that grows with the learner and, much like the exponential growth of information that drives many aspects of our society, provides continual challenges so that instruction can truly be individualized. In this respect, Ten Sleep teachers believe that all of their students are gifted learners and that any applied, technologically driven learning environment must continually address the needs of the learner.

SUMMARY

There have been several instances at the Ten Sleep school in which second-grade students, for example, were able to become more adept with new technologies *faster* than their teachers. It appears that when exposed to this type of applied learning, students are able to organize and process new information in a manner that allows them to build on what they have already learned, with careful guidance and facilitation from teachers but without much teacher intervention. Experience suggests that constructivism is a sound educational strategy and one compatible with ESTE.

It is also clear that ESTE should not consist of "watered down" middle–school activities. Elementary students are capable of learning much more about technological devices and processes than previously thought. Elementary students have mastered material that was formerly reserved for older students. The only concern at this point is what can they be "taught" in high school? They could be more advanced than their teachers by then!

The ESTE program in Ten Sleep, Wyoming, is proof that even small, rural districts can implement viable technology education programs. While small (single-teacher) programs may experience obstacles absent in larger metropolitan or suburban programs, technology education can nevertheless assume an appropriate position in the school—at the core of the curriculum!

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Section III Theoretical Considerations

OVERVIEW

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Earlier sections in this volume have provided guidance and direction to the practitioners and supervisors of elementary school technology education (ESTE) and gave insight into the concept of technology education as it is practiced in the elementary schools. This section, with chapters on preservice and inservice education of teachers and an overview of the relevant research, gives insight into methods of determining content and application for ESTE.

Teachers and administrators are beginning to recognize the benefits of ESTE as an effective pedagogical tool. Efforts should be made to take advantage of this increased recognition to advance the implementation ESTE. Given the social, political and economic influence of technology, the authors believe it is critical that students begin to learn about technology at an early age. In combination with other subjects, students should learn about technology in the elementary grades as they begin to build a common cultural literacy.

If teachers capitalize on the natural creativity, energy, curiosity and enthusiasm of the elementary school student, ESTE complements students' comprehension of subject matter. Among elementary school teachers, there appears to be a direct relationship between exposure to technology with the willingness to teach technology in the classroom.

PRESERVICE EDUCATION

The key element in the successful implementation of ESTE is the classroom teacher, Lewis Kieft says in chapter 10. A teacher must have interest and energy as well as some understanding of ESTE to successfully implement a program. Special challenges face such a teacher. Most preservice teacher training does not include ESTE, nor is it a requirement for most state teaching licenses. Elementary school teachers are simply not aware of the potential educational value of ESTE activities. Teachers who *have* had extensive training in technology education usually have been prepared for positions in the upper grades. But even with a good understanding of technological content, teachers will benefit from an understanding of successful implementation strategies, given existing crowded curriculums and limited resources.

If ESTE is to broadly infuse the elementary school curriculum, it will only happen with elementary classroom teachers acting as change agents, and they will become change agents for technology education only as strongly as they believe in the field. Appropriate preservice college courses and inservice training will help to instill this belief and significantly diminish the obstacles to incorporating technology in the elementary classroom.

Attention must be given to preparing preservice elementary school teachers be ESTE facilitators. Because of many demands on the curriculum, the most a college can offer is one technology course to prepare elementary school teachers. This course needs to be carefully planned to bring maximum benefit to the future teacher. An effectively designed course should include a rationale for ESTE, discuss the importance of possessing knowledge about technology and present the pedagogical advantages of ESTE relating to student motivation. Future teachers should become competent in the basic knowledge and skills needed to facilitate ESTE activities, understand how technology can be used to teach problem solving, encourage creativity and enhance the development of social skills. Teachers should be knowledgeable of the features of an integrated curriculum and the use of themes to articulate ESTE.

INSERVICE TRAINING

In chapter 11 Barry David in describes effective inservicing to effect the widespread implementation of ESTE. Elementary school teachers may have had little or no prior technology experiences as a child in school or in their preservice preparation. They have a natural hesitancy about teaching an area which was not included in their own elementary school experience or their preservice training. Further, teachers may feel overwhelmed by the challenge to incorporate yet another subject in their day.

Obstacles to implementing ESTE include time and resources. Inservice activities should be as experiential as possible. Workshops are an effective method to reach many teachers economically. They should provide the opportunity for the teacher to develop a sense of ownership, internalization and the opportunity to cooperatively share their experiences with other teachers. Inservice activities must be well planned and focused on usable and easily transferable ideas that teachers can take back to their classrooms. Inservice activities should include a good mix of theory, modeling, practice, feedback and coaching. Such activities help teachers become aware of the references and resources available to complement their ESTE efforts.

Inservicing can help to insure the successful implementation of ESTE. Teachers who participate in inservice activities will become comfortable with both the content and methods of ESTE. With this confidence and a strong belief in technology education, a teacher can infuse a new life into their curricula.

RESEARCH

Although often presented as new, ESTE has a long history—more than 100 years, says Karen Zuga in chapter 12. There is, however, a relatively small body of research relating to teaching ESTE.

This research has consistently identified a common ideological commitment toward ESTE. Research has also be used to evaluate the role that technology education has taken in elementary schools by examining topics such as student attitudes, teacher education preparation standards, effects of student on traditional school subjects and the unique value of teaching about technology in the elementary grades. However, more extensive research is needed to support and illustrate the benefits of incorporating technology into elementary school curriculum.

Zuga's review of the literature reveals that there is a need for studies that demonstrate the need for children to study technology, and she suggests approaches for this research. She asks, what do students gain from exposure to technology education? What is the value of technology education as distinct from science education or other subjects? Further research can demonstrate the relationship of ESTE to the curriculum. Zuga suggests directions for further study in ESTE. Future research, she says, must identify the priorities needed to identify the future direction of ESTE. Research is needed in curriculum and integration, and in identifying the factors which make a smooth implementation of technology education into the elementary school possible. When these research questions are answered, we will have a clearer understanding of what technology concepts are appropriate for elementary school children.

Chapter 10

Teacher Education

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Imagine an environment in elementary schools where technology education is considered a significant part of every child's development and where a curriculum plan exists that coordinates the development of technological learning at each grade level and integrates technology education with the total school curriculum. In this environment, teachers from different classes and-grade levels would work together to plan, share ideas and coordinate efforts to ensure that all children will have the best possible learning experiences. This environment would have children involved in learning about technology participating in technology education activities every day.

The students would be excited about their experiences and take great pride in their achievements and learning. The teachers would be pleased to see the progress being made and realize the outcomes achieved by the children are well worth their efforts to prepare and implement the learning experiences. Parents would be enthusiastic about the positive attitudes their children were developing towards school, their learning experiences, and themselves. The principal would recognize that positive outcomes were being achieved and would demonstrate substantial support by occasionally participating, commending the efforts of those involved, and working extensively to acquire funding to support the programs and activities. This application of elementary school technology education (ESTE) would have very positive effects on the overall development of the children, and everyone would realize that the children were becoming more technologically literate.

NOT YET A REALITY IN MOST SCHOOLS

Although this type of educational atmosphere and emphasis on technology education could be a reality in all elementary schools, it presently exists in only a few. Dynamic leadership, major curriculum reform and special program funding are often the foundation needed for this atmosphere. Even when a successful program has been implemented, it may not last; there are several examples of successful elementary school technology education programs becoming less functional and visible when their funding or leadership was lost. In many other schools, commendable but intermittent attempts are being made by individual teachers to implement ESTE. These teachers often work by themselves to plan and prepare educational units and activities. They are creative and provide exciting and successful learning experiences for children. Their level of success often depends upon the amount of time, effort and resources they have available. In other schools, there seems to be little or no visible efforts to implement ESTE. Some possible reasons why some teachers don't get involved will be identified later in this chapter.

GROWING SUPPORT FOR IMPLEMENTING TECHNOLOGY EDUCATION

The importance of increasing the technological literacy of children has been well established (AAAS, 1992; Dyrenfurth & Kozak, 1991). Technology is an important factor in everyone's life, and a certain level of technological literacy is needed to function effectively in our society. Children become involved in using technology at an early age as they learn to use tools, devices, and appliances in their homes. Their level of functioning is increased as their understanding and use of technology increases.

Technology has already gained recognition for its value in facilitating learning in elementary schools. In recent years, many schools have provided additional opportunities for teachers and children to use more advanced devices such as computers, calculators, FAX machines, VCRs, and video cameras. These opportunities are referred to as "educational" or "instructional technology" and focus primarily on the technological processes of helping children learn (Schmitt, 1995). Considerable evidence suggests that educational technology places a growing emphasis on helping children improve their knowledge and use of many other technologies, creating the incentive for more elementary schools and teachers to becoming involved in implementing ESTE.

Several types of services have also improved with the increased interest in ESTE. A greater variety of ESTE curriculum materials and publications, such as texts, workbooks, videos and teachers guides, are now available from professional organizations, state and local school districts, and publishing companies (e.g., Virginia Department of Education, 1994). Commercial sales catalogs now advertise many new educational products such as tools, machines, materials, activity kits, and teaching aids that are appropriate for helping children study and use technology (e.g., Carolina Biological Supply Co., 1995). Increasing numbers of workshops and presentations are being offered at the national and state levels to help teachers become familiar with ESTE. Many field trips and classroom activities provide children greater opportunities to learn about technological processes in the home, community, state, and country.

ESTE provides new opportunities for children to learn about technology and to use technological processes to solve problems and complete tasks. It is expected that elementary schools in the next decade will continue to help children expand their knowledge and use of technology because many of the conditions necessary for implementing ESTE already exist. Three such conditions are that children are interested in learning about many aspects of technology, that many exciting activities have already been developed and tested, and that parents and school administrators are willing to support programs that result in positive learning experiences for children. However, for ESTE programs to become a reality in most elementary schools, several factors must successfully be addressed. The most important factor is the ability and desire of elementary school teachers to participate in the growth of technology education in elementary-grade levels.

A CRITICAL ELEMENT FOR SUCCESS

The involvement of well-trained, energetic and creative elementary school teachers will be a significant factor in the success of most ESTE programs. If children are to learn about technology, they must have some assistance. They will not achieve an adequate understanding if they are left to discover technology on their own. Children will need considerable guidance, direction and appropriate learning experiences, if they are expected to develop an adequate level of technological literacy. In a few elementary schools, this guidance may come from a technology education consultant or special teacher. In the average elementary school, however, it is more likely that this guidance will come from the classroom teachers.

ROLE OF ELEMENTARY SCHOOL TEACHERS

There is little doubt that the efforts and performance of elementary school teachers are significant factors in educating children. They provide the guidance for most of the learning experiences children have in the elementary school. The teacher's knowledge, efforts, actions, and attitudes are important factors contributing to their effectiveness as teachers. Their ability to motivate and challenge elementary school children is one of the most notable of these factors. Often this motivation can consist of involving students in a variety of exciting learning experiences.

Elementary teachers who provide exciting and unique learning experiences for their children are often recognized for their efforts. One survey of exemplary elementary school programs indicated that just about every elementary school teacher at every grade level implemented some type of hands-on activity each day. These teachers indicated that they could use the motivation generated by these activities to propel students into increasing their overall learning. Students had concrete experiences to which they could relate, and plenty of opportunities to test their own creativity and ideas (Penick & Yager, 1987).

REASONS FOR LACK OF TEACHER INVOLVEMENT

If hands-on learning experiences are important for children, why don't more elementary school teachers provide ESTE experiences for children? The answer to this question is not simple. One informal survey indicated several reasons that many elementary school teachers are not significantly involved in implementing technology education. Reasons mentioned by teachers include:

- "I'm not required to teach it."
- "I'm not familiar with technology education."
- "I don't have enough time to get involved."
- "I don't have any good ideas for activities."
- "I don't have much confidence about teaching about technology through the use of activities."
- "I don't have any tools and materials to use with activities."
- "Some of the activities might be too dangerous for children."
- "We don't have any funding for any new programs."

Although many of these concerns are valid, they have not prevented some teachers from becoming involved. Most of these reactions can be condensed into one significant point: a large number of elementary school teachers are not aware of the potential educational value of technology education experiences and have not had adequate training and preparation to effectively implement ESTE. However, the knowledge and experience could be provided through teacher training programs, which would help eliminate many of these teacher concerns. Once teachers become aware of the purpose and nature of technology education, they would be more likely to implement successful ESTE experiences for children.

PREPARING ELEMENTARY SCHOOL TEACHERS

As is pointed out in chapter 1 of this volume, if students are to develop an adequate level of technological literacy, ESTE must to start at an early age. A similar statement can be made of elementary school teachers. If teachers are to develop an adequate knowledge about ESTE, it must be incorporated early into their training and should be part of their preservice preparation. This implies a step-by-step process.

The first step is awareness through preservice training. Teachers need to have adequate information about ESTE before they can make decisions about when and how to use it and implement it effectively. Currently, there are elementary school teachers who involve their students in various types of hands-on activities in the classroom, not realizing that the children are using technological processes and learning about technology.

After acquiring a basic level of knowledge regarding technology education, teachers will apply the second step by implementing ESTE experiences in their classrooms. As teachers progress in teaching more advanced concepts and as they seek to employ more elaborate learning activities, they will see the necessity for more knowledge and training. Obtaining this knowledge comprises the third and final step: inservice training.

Without participating in these steps, elementary school teachers are unlikely to be successful in integrating ESTE into their curricula. Some basic knowledge is needed to implement a variety of ESTE experiences, yet the amount of preparation time for elementary school teachers is usually very limited. Attempting to learn without assistance is often difficult, time consuming and frustrating. To receive adequate training and preparation, teachers need to participate in both preservice and inservice experiences.

The focus of this chapter is to identify methods of preservice—preparing undergraduate students majoring in elementary education to integrate technology education into their first teaching experiences. In the next chapter, Barry David discusses inservice workshops and conferences. Preservice training for ESTE should be provided by teacher training institutions in the form of one or two required or elective courses. Additional preparation should also be provided during student teaching and other special culminating experiences in the teacher education program.

UNIVERSITY TEACHER TRAINING PROGRAMS

Teacher training programs at universities have provided most of the preservice training for preparing elementary school teachers to implement ESTE. If capable elementary school teachers are crucial to the successful implementation of ESTE programs, then their preparation and training should be treated as crucial. Several universities offer one or more courses relating to technology for elementary education majors. Some of these courses teach the student how to use technological equipment, while others teach students how to implement technology education.

The courses that focus extensively on computers and video equipment and are referred to as *educational technology* (Schmitt, 1995). These courses prepare teachers to use this equipment for educational purposes. Although, this application of technology is important, it represents only a part of the benefits children can achieve from learning about and using technology.

Other university courses provide elementary school teachers with more comprehensive knowledge relating to the implementation of technology education. Course of this nature have titles such as: "Technology Education for Children," "Elementary Technology Education" and "Teaching Children About Technology." These courses provide elementary education majors with a wide range of concepts and learning activities relating to technology. In some teacher education programs, one such course is required for all students in the elementary school teacher education program. The course will often be taught by faculty from a technology education or industrial education department.

While one introductory course is usually not adequate to prepare elementary school teachers to feel confident in addressing all the aspects of an ESTE program, such a course can provide enough information and knowledge to allow teachers to initiate a variety of learning experiences. However, this preservice program may be the only significant introduction and training for ESTE that many elementary school teachers will receive. It must be carefully developed to be a catalyst for future teacher involvement. One purpose of this chapter is to identify and examine the main features that should be considered when developing an introductory technology education course for elementary education majors. Although several of the recommended components of an introductory course should be discussed separately, most will be implemented concurrently.

ESSENTIAL COMPONENTS FOR A PRESERVICE TECHNOLOGY EDUCATION COURSE

Characteristics of Elementary Education Majors

In a typical class of prospective elementary school teachers, characteristics of the students are likely to vary considerably. For this reason, certain characteristics of the students enrolling in the course should be identified before determining the content, developing learning experiences or making assignments appropriate for an undergraduate technology education course. Some of the characteristics demanding consideration include: interest in teaching, curriculum majors, knowledge of and experience in technology, maturity, and experience working with children.

Interest in teaching It is likely that students in the course will have different levels of interest and motivation concerning the teaching profession. Some students may just be starting college and have only a tentative commitment to teaching. It may be several years before they have opportunity to teach in their own classroom. Other students may be finishing their degree and demonstrate a sincere interest in becoming better prepared and extensively involved in class activities.

Curriculum majors Some courses may include only elementary education majors. Other courses may also include secondary technology-education majors and special-education majors. If an introductory course does include students with different curriculum majors, it is important that all students in the course perceive the content and learning experiences as relevant to their area of teaching. Therefore, instructors should ensure that content, references, activities, and assignments are appropriate. In some situations, the instructor may allow students to modify an assignment so that the learning experience is more relevant to their areas of study.

Knowledge and experience regarding technology The students' interest, experiences, and confidence in technology may be considerably diverse. A few students may have already completed one or more technology education courses in their middle or senior high school. Their confidence and experience levels will be high. For others, this course may be their first formal experience in technology. Their confidence level may be low and they may have great apprehension about their anticipated performance in the course.

Maturity Maturity and age levels may also vary considerably in an introductory course. Some of these college students may be young and may lack the maturity to function confidently in groups or to work independently to solve problems effectively. Other students may function more effectively because they have more education and life experiences.

Limited experience working with children Elementary teachers working in the classroom often have opportunities to implement new ideas immediately. Many also have extensive experiences that may be shared with others in discussions. However, most elementary education majors have only limited experiences in educating children. This factor often limits the type of discussions, assignments, examples, and activities that would be appropriate in an introductory course. The instructor of this course can determine some of these potential differences by surveying students at the beginning of the course. It is important that the instructor be aware of significant existing differences and the problems that might result. Encouragement, praise and even adjustments in assignments and activities may be needed to reduce anxieties and increase performance.

Thematic Units

An important part of course planning is identifying the course goals or outcomes. The most significant outcome may be for students to gain the knowledge and experiences necessary to effectively implement ESTE. The instructor must ensure that the focus of the course remains on ESTE and its integration with other subjects, and not on developing isolated learning experiences in other disciplines. This integration is best achieved through the development and use of thematic units that include information relating to technology.

Thematic units can integrate ESTE with traditional school subjects such as mathematics, science, language arts, and social studies. To ensure that a thematic unit places a major focus on technology, the following information and experiences should be considered:

- An introduction and rationale for implementing ESTE in classrooms should be presented and discussed.
- Areas of study and concepts relating to technology that are appropriate for both teachers and children should be identified.
- Appropriate types of ESTE experiences should be identified.
- The purpose and characteristics of these activities should be discussed.
- Opportunities for student participation in many hands-on learning experiences should be an important feature in the course.
- Examples and discussions of integrating concepts from other subject areas (math, science, social studies) into ESTE experiences should be included.
- Methods of using ESTE as an integrator of the elementary school curriculum included.
- Methods of using technology learning experiences to reinforce critical thinking and group dynamics should be presented and discussed.

- Students should have opportunities to experience problem-solving learning experiences.
- Students should have opportunities to work in groups.
- Appropriate examples should be used during the course to support ideas and concepts presented.
- Resources available to teachers should be identified and available for use by students.

The Course Introduction

The introduction to a technology education course designed for elementary education majors is very important because it may be a "first impression" of ESTE for many students. As previously noted, students enter the course with different expectations, perceptions, feelings and levels of confidence. The perception of ESTE developed at the beginning of the course will affect their efforts, receptivity to learning, and their performance during the remainder of the course.

These perceptions will be more diverse if the course is required, because some students have enrolled without reviewing the catalog description of the course. Some students may be questioning why they must take the course. Other students may be eagerly waiting to get involved in the first discussions and activities. The introduction may last several class periods and should include several methods of providing information to students. Initial discussions might focus around questions such as:

- What is technology?
- How can a knowledge of technology help children?
- What is ESTE?
- What are some concepts relating to technology that should be taught to children?
- How is ESTE implemented in most elementary school classrooms?
- What are some sample ESTE activities?

- What are some outcomes that can be achieved by children participating in ESTE activities?
- What are some examples of existing ESTE programs?
- How is ESTE blended into the curriculum?

Several methods should be used to assess the students' existing knowledge and to answer the above questions. A pre-test might help the instructor identify some of student expectations and some of the student knowledge and skills. A film, video or slide presentation showing children involved in successful ESTE experiences can help prospective teachers begin to develop an awareness of various types of technology education learning experiences. Brief activities may be used to get students involved in manipulative activities early in the course. Activities can also generate motivation, which should remain high during the entire course.

The course introduction should also convince elementary school teachers must be convinced that a knowledge of certain technological concepts can be of great value to children. They must believe that the ESTE experiences they provide for children can have great potential for learning.

Elementary teachers should also become aware of the many additional benefits that can be achieved when children participate in technology education learning experiences. Some additional benefits discussed during the course introduction should include the importance of providing opportunities for children to:

- increase their levels of motivation,
- reinforce concepts from traditional school subjects (science, math, social studies, and language arts),
- improve group dynamics,
- develop critical-thinking and problem-solving skills, and
- increase awareness of career education concepts.

Undergraduate students must develop confidence so that as teachers, they will be capable of preparing and implementing a variety of exciting learning experiences for children. This can be achieved during the course introduction.

Identifying Course Content and Learning Experiences

A number of curriculum guides that identify and organize technological concepts appropriate for study by children have been developed by professional organizations, state departments of education and school districts. When a new university course is developed, instructors often use information these curriculum guide to develop outcomes, assignments, and learning experiences. This information can help elementary school teachers identify areas of study for their classes. However, few curriculum guides identify outcomes to be achieved in a preservice course for elementary education majors. Additional information and experiences must be provided to undergraduate students if they are to be prepared to implement ESTE.

The introductory course should include discussion and experiences that result in the following outcomes. Elementary education majors enrolled in an ESTE course should

- increase their technology literacy,
- identify technology concepts appropriate for children to study,
- identify appropriate methods of implementing ESTE experiences,
- identifying methods of using ESTE to integrate learning from school subjects, and
- identify experiences that use ESTE to help children develop critical thinking skills.

When structuring an introductory course, instructors should consider the amount of emphasis placed on helping elementary education majors learn about the differing aspects of education, such as the technological literacy of these majors, the implementation of a variety of hands-on learning experiences, integrating learning from several school subjects into a ESTE activity and providing problem-solving experiences. Most undergraduate students will have only a limited background in each of these areas and will need considerable training in all of them. Although all of these areas are important, the amount of class time devoted to each area may vary considerably.

Identifying and Organizing Content

Most elementary education majors use technology extensively but have difficulty in describing it. They have not given much thought to how it provides benefits and problems in their lives. General discussions about the nature of technology, its evolution, and its impact on people's lives should take place early in the course. This can provide a foundation of knowledge that will be useful as they implement technology education experiences with children. This knowledge includes the ability to identify the types of concepts appropriate for ESTE and the ability to lead children through related learning experiences.

To help increase preservice teachers' technology literacy, samples of a variety curriculum guides should be available for their review during the course. Curriculum guides can help students realize that the technology content may be derived from different sources. In some elementary schools, ESTE may be used to integrate the curriculum, so subject-specific ESTE objectives should be illustrated to prospective teachers.

An introductory course should help increase elementary education majors' technology literacy by giving them the knowledge to identify basic concepts which relate to many technological processes and situations. These concepts form the foundation of technology education and should be incorporated into a unit of study to reinforce learning experiences. However, since no single ESTE implantation plan has received widespread acceptance and usage, elementary school teachers should be taught the knowledge and experience necessary to identify and organize their own curriculum materials. Elementary teachers should know how to include technology content in a unit of study and identify information regarding technology that can be taught during the unit. A well-designed introductory ESTE course for preservice teachers should provide some opportunities for students to gain experience in identifying relevant content and organizing it into a lesson.

Identifying and Organizing Learning Experiences

Once a course has addressed how to identify and organize technology content, it can prepare students to implement ESTE experiences with children. ESTE involves children in authentic processes using tools and materials. The learning experiences children participate in should reinforce the concepts they are studying. Elementary teachers are encouraged to involve their students in considerable activity as they learn about technology. Therefore, elementary school teachers must not only have a considerable knowledge about technology, but must also have the knowledge, confidence, and skills to select, develop, implement and evaluate appropriate learning experiences for children. Teachers must be aware of the purpose and characteristics of various activities. They need knowledge concerning appropriate tools, materials, and processes.

Focusing on Content or Activities

The instructor of the preservice course needs to determine if more emphasis should be placed on training teachers to provide appropriate learning experiences for children or on helping teachers learn about technological content.

An informal survey was conducted with teachers from several states to determine if they felt more prepared to teach technological concepts or to implement technology-based activities. Almost all of the elementary school teachers surveyed felt they had more confidence in identifying content to teach than they did in implementing unique hands-on learning experiences designed for children to apply technological concepts. They felt their greatest need for training was in the area of developing and implementing appropriate hands-on activities. This information indicates that in an undergraduate technology course a substantial amount of the course should be devoted to helping elementary education majors learn to plan, prepare, implement and evaluate technology-based learning experiences for children. However, the instructor should base the course's emphasis on the ability and knowledge of the students in individual sections of the course.

Preservice experiences in implementing technology education

In a preservice ESTE course, the best learning will likely come from direct involvement. The instructor should provide opportunities for preservice teachers to experience many of the concepts presented and discussed. Several types of direct experiences should be provided for all students in the course. These are as follows.

- Opportunities should be provided for students to participate in outlining lesson or unit plans which employ ESTE. This should include experiences in selecting and organizing both content and learning experiences.
- Students should have opportunities to work in groups and experience some of the group dynamics which may be factors in the success of the activities.
- Students should have opportunities to participate in problem-solving and critical-thinking activities. This participation will provide experiences useful for discussing and planning the use of similar activities with children.
- Opportunities should be available for students to assist children as they participate in hands-on ESTE activities.
- Students should have opportunities to integrate ESTE with other subject areas.

Establishing an Educational Plan

Undergraduate students should become aware that there are several methods of implementing ESTE in the curriculum. Having aa educational plan is important to the successful implementation of any of the methods. There are several approaches to incorporating an educational plan into elementary curriculum.

One approach used by elementary school teachers is to involve children in solving a technological problem. Elementary education majors involved in this type of activity will gain considerable knowledge regarding the implementation of problem-solving activities with children. This knowledge may include becoming more aware of problems created by the use of technology. It may include identifying types of problems appropriate for elementary school children to attempt to solve. It can include knowledge of the problem-solving process and how it should be implemented with children to develop brainstorming and critical-thinking skills without becoming frustrating for children.

Another approach used by elementary school teachers is to involve children in a thematic unit of study. Discussion of the characteristics of thematic units will be useful for undergraduate students, so they may be prepared to develop units for use in their future classrooms. Such units are motivational, having interesting titles and offering considerable opportunity for students to participate in a variety of learning experiences involving the integration of concepts from several areas. Hands-on activities often demonstrate technological processes that relate to the unit. Units can often be modified to be suitable for children of different ages.

The Unit of Study and a Sample Activity

The unit of study includes assignments and learning experiences that can provide elementary education majors with insights into each of the recommendations presented above. Units of study can be used to effectively provide opportunities for students to apply some of the concepts discussed during the course. Listed below are the components necessary for a successful unit of study. Each section that discusses a needed component will include an example of how this component was incorporated into a technology-based, hands-on learning experience entitled "Harnessing the Wind," which is very similar to activities that have been successfully implemented in several elementary classrooms.

Designing a Unit

When designing a unit of study, the initial task is to identify important components of a lesson plan that will be appropriate for a specific group of children. Content and learning experiences must be selected and organized. Activities should be selected because they are successful learning experiences for children and are motivational, challenging and offer ample opportunities for children to learn about technology. Since many students will have little or no prior experience in developing a lesson plan and several different activities are appropriate for units of study, the instructor must ensure that the final plan is workable and includes the appropriate learning experiences desired. The preservice teachers should also have opportunities to discuss the purposes, advantages and disadvantages of involving children in group work.

The instructor may want to divide the education majors into groups so that each group can focus on the development of one area of the lesson plan. Group dynamics are an important factor when determining the success of an activity because they facilitate the anticipation and discovery of potential problems in the activity. Developing the unit in a group will also afford these undergraduate students the opportunity to participate in activities similar to the types of activities they may someday use with children.

Harnessing the Wind is an example of a thematic unit appropriate for children who are involved in investigating wind energy. The unit includes written and visual materials, discussions, and hands-on activities relating to the different technological methods people use to harness energy from the wind. This unit can be taught as an individual, small-group or class activity. The areas of investigation and study relating to technology include:

- early inventions,
- purposes for using the wind,
- types of wind vehicles, and
- aerodynamic designs for vehicles.

During the unit, reinforcement of concept from other disciplines might include:

- discussion of concepts such as friction, momentum, and force;
- measurement and cost calculations;
- historic events involving wind power; and
- writing a brief story concerning how people use the wind, or how it has caused problems.

Other learning experiences that may be included in this unit include the following.

- A video titled "How to Sail."
- A picture bulletin board of uses of the wind.
- Demonstrations of friction and momentum.
- Hands-on experiences where children become involved in constructing and testing a device that converts wind energy to mechanical energy.

Developing a hands-on activity

Elementary education majors should be aware that each activity has positive and negative characteristics and that some activities will be more appropriate than others. Teachers should be aware of the criteria necessary to select the best activities for their students. Starting with a good activity will increase the chances that the children involved will gain knowledge and feel successful. *Harnessing the Wind* was selected because it is an example of an exciting, versatile and successful hands-on learning experience.

Designing, constructing, and testing an assignment

This section will be a consideration of one activity focused on wind energy—the development and testing of a wind vehicle.

Every unit of study assignment should offer a challenging opportunity for preservice teachers to design and apply ideas for children at several grade levels. The number of options for design are almost unlimited. The elementary school teacher can modify the assignment for grades K-6 by changing the amount of structure and guidance provided in the activity. The assignment should have considerable appeal for elementary education majors and should serve to demonstrate many of the concepts of ESTE.

Discussion of the activity is essential to ensure that students understand its purpose and nature. Preservice experiences should include enough activities so that students are exposed to most of the materials, tools and processes they may need to function effectively in using technology education. Both instructor– and student–generated questions are important. Students should be involved in considering following topics.

- What outcomes will this activity likely achieve?
- How could the activity be modified to focus on different outcomes?
- How could certain specific technological concepts be reinforced during this activity?
- How could concepts from other traditional subjects (language arts, math, science, social studies, etc.) be reinforced?
- What processes seem to be difficult and how could they be made more straightforward?
- How could this activity be modified for students of different age levels?
- How could it be modified to provide a greater or lesser challenge relating to problem-solving?
- How could it be modified to provide a greater focus on group dynamics?
- What other types of problems might be anticipated when conducting this activity with children?

Harnessing the Wind can be used as a reference to teach undergraduate students many of the concepts they will need to function effectively when teaching technology education to children. However, it is only one of many activities that could be used.

A typical wind vehicle constructed by children is about one foot in length and has three or four wheels. The wheels can be made from recyclable materials, such as metal or plastic lids from empty containers. The frame can be made from heavy paper, small pieces of wood, Styrofoam, or acrylics. The sail frames can be made from coat-hanger wire or from thin strips of wood. Light cloth, paper or bag material can serve as the sail. During this activity, undergraduate students will use many of the same materials, tools and processes that children would use in the classroom. When the vehicle is completed, students enter their vehicles in competition—or they may simply test them—to determine how quickly the vehicles can accelerate and how far they can travel. Energy is provided from the wind, which will be simulated by an electric fan. If space and proper wind conditions exist, the testing may be done outside.

PROVIDING DIRECT EXPERIENCES WITH CHILDREN

After undergraduate students have had an opportunity to participate in the development of a unit of study and have analyzed it, one more exciting learning experience can take place that will reinforce many of the concepts discussed. It is strongly recommended that the instructor provide one or more opportunities for undergraduate students to work directly with children. Preservice students can become directly involved in assisting a class of elementary school students in designing, constructing and testing. This may take place in a nearby elementary school classroom or at a university when elementary school children participate in a field trip. Many elementary school teachers can be identified in any community who are eager to have their class participate in an exciting and organized learning experience of this nature. Undergraduate students should work with the instructor to ensure proper planning and supervision of the activity. A few problems may develop during the activity that will require immediate solutions or modifications. Discussions are also essential after the childrens' activity is completed to ensure that all concerns have been addressed and that the most positive aspects of the activity have been recognized.

PREPARING PRESERVICE TEACHERS TO ORGANIZE THEIR CLASSROOMS TO FACILITATE ESTE

Although most ESTE activities can be implemented in a typical classroom, some modifications will often be helpful. Modifications may include adding or designating a resource area, a work area, a display area, or a storage area. An introductory college course should be held in an area that includes at least the minimum facilities that would be ideal for an elementary classroom. Elementary education majors can become familiar with the purpose and use of these conditions as they participate in their first technology education experiences. Additional resources and an expanded work area may be necessary for large numbers of elementary education majors to participate in similar activities at the same time. Specific information discussed in an introductory course regarding classroom facilities should include:

- **The design and resource area.** Appropriate resources for children and teachers should be available. A variety of books, pictures and videos could be used by children as references or as browsing materials. Computers, VCRs, and video cameras may be used in both the reference area and the work area. Elementary teachers may also use this area to develop units of study and activities.

- **The work area.** This area may include several tables or benches that should be mobile to accommodate various types of activities. In addition, protection of desks and other classroom furniture and accessories should be considered. Ample room for the tools, machines and materials should be available.

Safety in the work area should be stressed. Location of electrical outlets may be important for some activities. Clean-up procedures should be identified and used.

- **The display area.** Many students will be very proud of their efforts and accomplishments in ESTE activities. Teachers should have a special area designated for students to display their work. This area should be visible by students from other classes and to visitors to the school.
- **The storage area.** Adequate storage is important to ensure success of the activity. Tools and machines should have a permanent storage location. Most activities will involve various materials that should be easily accessible during the activity but out of the way the rest of the time. During many activities, children will have projects that are partially completed. They will need to be stored in a secured location where they will not be lost or damaged.

SUGGESTIONS FOR MAKING THE COURSE A SUCCESS

Every introductory ESTE course for preservice teachers should have certain qualities that encourage and facilitate student learning. Characteristics of a good course typically include: organization, motivational learning experiences, equitable evaluation, clearly identified classroom procedures, and opportunities for students to ask questions and express viewpoints. In addition to these features, the course should include the following outcomes.

High motivational levels

It is important that the first experiences preservice teachers have in a introductory ESTE course should be positive. If they are motivated during their first learning experiences and feel good about the results they will be more likely to provide technology education learning experiences for their students.

Feelings of success

Learning experiences that result in feelings of success are also very important. The more successful a preservice teacher's first ESTE experiences are, the more likely that teacher will be to implement ESTE in the classroom. This may be especially important during activities involving problem-solving.

Occasionally, elementary school teachers place considerable emphasis on a construction process and little emphasis on how the final model looks or works. Placing an emphasis on precision and good artisanship can encourage students to develop good work habits and increase their pride in their accomplishments.

Learning experiences

Elementary education majors should become aware of guidelines and techniques for implementing a variety of ESTE experiences. These learning experiences may include educational games, demonstrations, role-playing and simulations, video productions, experiments and problem solving and hands-on activities in which children have opportunity to use tools and materials to complete processes. Undergraduate students should have an opportunity to participate in as many activities as time permits. As they participate, they will gain insights as to the purpose and methods of implementing similar learning experiences with children.

Written guidelines

Written information concerning the implementation of ESTE activities should also be provided for students to use as a reference after they begin teaching. Guideline sheets should include

- a description of the activity;
- the purpose of the activity;
- steps the teacher must complete to prepare the activity;
- a list of tools and materials necessary for children to complete the activity;

- sequential tasks needed to complete the activity;
- safety concerns;
- concepts to be taught regarding technology;
- suggestions for integrating information from other disciplines such as math, science, social studies; and
- suggestions for making the activity successful.

STATUS OF UNIVERSITY PRESERVICE COURSES FOR ELEMENTARY SCHOOL CURRICULUM MAJORS

In the past, many universities have provided one or more preservice courses for elementary education majors to receive an introduction to methods for helping children learn about industry and technology. The 1974-1975 ACIATE Industrial Teacher Education Directory (Dennis, 1974) identified more than 40 universities and colleges that provided at least one course focusing on the implementation of industrial arts/technology for elementary schools. Most, if not all, of these courses provided preservice training for elementary education majors. The 1994-1995 edition of the directory (Dennis, 1994) shows a significant change has taken place. Only five universities are identified as having a course that focuses on ESTE.

One of the main reasons for this is that as new requirements are added to preservice programs, cuts must be made. The ESTE courses seem to be one of those most vulnerable.

An analysis of the goals, content and learning experiences of most of the existing university elementary school courses was done by Foster (1994). In all of these courses, the development of hands-on activities for children and the integration of technology education into the elementary curriculum were considered two important outcomes in the majority of the courses surveyed. The implementation of preservice technology education courses would help meet these desired outcomes.

DEVELOPING PRESERVICE TRAINING

Since different philosophies exist at different teacher education institutions, one single approach will not be suitable for all elementary school technology education courses. In most situations, ESTE instruction will be provided by faculty with a technology-education background.

When a preservice ESTE course is developed, it is important to involve educators from the college of education who are responsible for the elementary teacher education program. Many teacher educators will have only a limited understanding of the purpose and nature of ESTE. A rationale for the purpose of the course and the learning experiences will likely be helpful in gaining their support. Successful ESTE experiences in local schools should be publicized to demonstrate the contributions and value of ESTE. Support gathered from teachers in local elementary schools will also help convince educators at the college or university that an ESTE course should be a part of the preservice program.

OTHER APPLICATIONS OF TECHNOLOGY BY ELEMENTARY EDUCATION MAJORS

Elementary education majors may have several ways to apply the knowledge they have gained in an ESTE course. If elementary education majors become aware of the nature and potential benefits of technology education during their teacher preparation program, they will have additional time to use and expand their knowledge of technology education. They will be able to integrate ESTE experiences into other undergraduate teacher education courses relating to curriculum areas such as language arts math, science, and social studies.

Capstone course

In some teacher education programs, students are required to complete a "capstone" course during their senior year. This course requires them to apply much of the knowledge and many of the skills they have acquired. It may require them to develop and implement a complete unit of study. For students who have completed a course in ESTE, the design and development efforts in their capstone course can involve ESTE in several ways, including opportunities to help children learn more about technology and opportunities to involve children in hands-on learning experiences involving tools and materials.

Portfolios

A growing trend in preservice education programs is to require portfolios of students. These portfolios are a collection of information regarding the educational learning experiences and performance demonstrations completed by the students. They identify ways the undergraduate student has applied concepts and used teaching techniques to enhance learning related to various disciplines. Students completing a course in ESTE can include ways they have referenced or focused on technology education as part of their professional development.

Student Teaching

Most elementary education majors must complete a student teaching experience with children before they graduate. Often, they are required to develop and implement a large unit of study for the children. This requirement is an excellent opportunity to implement ESTE experiences into the classroom. The instructor of the college or university ESTE course may serve as a consultant to the student teacher to ensure that the activities used will be successful. This instructor may also be willing to provide assistance in preparing materials and in loaning equipment.

SUMMARY

As other authors in this volume have noted, ESTE is expected to be an important part of the elementary school curriculum in the coming years, and elementary school teachers will be responsible for the success of the learning. Informed and well-trained teachers

- can make better decisions about what and how to teach because they will have more options to consider and more skills to implement the activities;

- have a great level of confidence in implementing technology education; and
- will be more successful in implementing technology education because they can avoid some of the problems that might occur if they tried to implement technology education with very little training. Teacher training institutions will be mainly responsible for preparing elementary technology education majors to implement technology education in their future classrooms.

Preservice teachers will leave these courses feeling motivated and knowledgeable and will have participated in some very positive learning experiences. As teachers, they will implement ESTE activities because they know that these experiences will be positive learning experiences for children.

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Chapter 11 Inservicing Teachers

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Technology education can most effectively be implemented in the elementary school grades with appropriate inservice education for the instructional staff. Most elementary school teachers have had little exposure to technology education (or industrial arts education) as part of their undergraduate or graduate education (see chapter 10). Fewer still are teaching in schools in which an elementary-school technology education (ESTE) program is in place. Consequently, with technology education being a somewhat foreign idea, the concept of teaching young children about technology can conjure incorrect images in the minds of elementary school teachers. Teachers to whom ESTE is a unfamiliar concept might imagine such programs as requiring sophisticated computer systems and/or other "high tech" gear, or engaging a select few "gifted and talented" students in individualized instruction or independent research. For those who have had experiences with ESTE or the integration of technology content in the elementary grades, those images are quickly dispelled. But for teachers without such experiences, their images are real as are their fears, concerns and doubts. Designed exclusively for changing behavior and attitudes and for developing general awareness of ESTE, inservice programs should result in a correct understanding of the vital role technology content and activities play in the elementary grades. Further, because of the misunderstandings and lack of prior knowledge, teachers need to gain not only knowledge of current curriculum and methods but also to develop an appropriate philosophical base.

INSERVICE DEFINED

In order to gain a perspective to discuss the inservice education of teachers, it is first necessary to define the term "inservice" as it applies to education. Implementation of an innovative or new curriculum, methodology, or practice may be viewed as a process involving a number of stages or components. These stages or components include any and all activities or programs intended to improve the skills, attitudes, understandings, and/or performance of teachers, administrators, school support personnel, and others directly involved with the education process. When these components take place after the teacher's undergraduate and/or graduate education or while the teacher is on the job, these programs are termed "staff development," "professional development" or "inservice education" (the three terms are commonly used interchangeably). The activities of the inservice education may occur on-site (within the school), or off-site (in a teacher center, at a college or university, or at any other suitable location).

NEED FOR INSERVICE

The implementation of ESTE will likely be unsuccessful if the educators involved with the program do not benefit from proper training. School improvement and the successful implementation of an innovative or new curricula, such as ESTE, are intimately related to inservice education. Fullan and Pomfret (1977) noted that a successful curriculum reform effort engages those directly involved with the change in learning *how* to do something new. The emphasis upon the word *how* is duly placed. Curriculum implementation as a process is and must be action–oriented. Introduction to a new or innovative curriculum without the benefit of application and action oriented instruction is an ill-conceived approach to school improvement and curriculum reform. Curriculum implementation efforts that merely involve school personnel in a passive learning of theoretical constructs with little or no application information provided generally result in failure.

If ESTE inservice programs are to be effective, an understanding of *how* to implement the program is paramount. Implementation should be action-oriented, resulting in outcomes that speak to implementation rather than merely establishing a rationale.

The following fundamental questions are to be given consideration when determining what information teachers need in order to establish an ESTE program.

- How will ESTE to be implemented?
- How will ESTE improve the learning environment?
- How will ESTE improve student performance and understanding?
- How will ESTE impact upon the teacher professionally?
- How will the teacher acquire the necessary resources and information to maintain an ESTE program?

The importance of inservice training for successful program implementation has been well documented. Goodlad (e.g., 1984) has suggested that school improvement efforts and staff development were intimately connected. The study further indicated that both school improvement and staff development consist of a process that requires sufficient time, strong leadership, organized structure, and continuous support. In discussing the establishment of an elementary school industrial arts program, Boyd and Brown (1980) stated that "a very crucial part of a successful elementary industrial arts program is the preparation of the teacher or consultant who is responsible for the operation of the program" (p. 28). They noted further that teachers need to be given opportunities to attend workshops or courses offered by colleges and universities so that they can get the needed training to conduct a program. Such inservice training opportunities will help alleviate possible fears or any reluctance on the part of the classroom teacher due to unfamiliarity with the program.

A meeting at the National Conference on Elementary Industrial Arts (1969-70) addressed the need for inservice programs to expand and reinforce the teacher's ability to understand the field of technology. It was noted further that inservice programs should provide teachers with the ability to analyze technologies in order that they may provide appropriate learning experiences for children (Hoots, 1980, p. 21). The need for proper staff development was also emphasized by Lauda and McCrory (1986) when they stated that proper inservice training enables teachers to comprehend the rationale, purposes, basic strategies, content, and evaluation procedures of the (technology education) curriculum (p. 39). Finally, Boyd and Brown, stressing the need for proper inservice education state that "the key to successful implementation of a program will depend upon the philosophy, objectives, organization, and effectiveness of the personnel who are responsible for its operation. The school principal and the classroom teacher at the operating level are the people who make the program function" (p. 27).

THE TEACHER AS CHANGE AGENT

Central to curriculum innovation are the classroom teachers who are the ultimate change agents within the school. Without teachers' acceptance and support, new curriculum efforts would be in vain. But teachers, particularly in the elementary grades, spend enormous amounts of time and expend great energy preparing to teach lessons in a wide range of diverse subject areas. The assumption that a teacher will readily put aside tried-and-true practice to immediately embrace a new idea is somewhat absurd. While teachers are generally open to new curriculum ideas and concepts, they rarely make the leap from general acceptance of a new concept to putting it into practice in the classroom. Change needs to be thought of as an incremental process that takes time and is accomplished in stages. If technology education is to be accepted and incorporated into the elementary school classroom, special attention must be given to the *individual* teacher as a key player in the change process (Loucks-Horsley & Stiegelbauer, 1991). Teachers need to be given the opportunity to "discover" the benefits of ESTE as an integral part of elementary education.

The Chinese symbol that represents the word "crisis" is depicted as two separate characters: one character represents *danger* the other *opportunity.* This symbolic representation of crisis correctly reflects the feelings of many teachers involved with the change process. Teachers rightfully have concerns about changes or innovations and may at first feel the threat of a crisis. Typically, teachers who perceive the new concept as a dangerous force try to reject it. In time, however, as teachers become better acquainted with the new idea and begin to recognize its benefits, they may develop a sense of opportunity, resulting in a more positive view. At this point, the teacher becomes less opposed to the concept, more comfortable with it, and may become an advocate of it. It is through this process of discovery that an effective implementation program might germinate.

The "Stages of Concerns About The Innovation" (SoC) model (Figure 1) is of assistance when trying to develop an understanding of the attitudes and concerns teachers might have about curriculum change. The SoC model may be used to identify teachers' responses during an inservice program as ideas and concepts are introduced. The SoC model also makes evident that teachers experience attitudinal changes as they are introduced to and begin to

- *Stage 0 Awareness:* Little concern about or involvement with the innovation is indicated.
- *Stage 1 Informational:* A general awareness of the innovation and an interest in learning more about it is indicated.
- *Stage 2 Personal:* Individual is uncertain about the demands of the innovation, his/her adequacy to meet those demands, and his/her role with the innovation.
- *Stage 3 Management:* Attention is focused on the processes and tasks of using the innovation on students in the individual's immediate sphere of influence.
- *Stage 4 Consequence*: Attention focuses on the impact of the innovation on students in the individual's immediate sphere of influence.
- *Stage 5 Collaboration*: The focus is on coordination and cooperation with others regarding use of the innovation.
- *Stage 6 Refocusing*: The focus is on exploration of more universal benefits from the innovation.

Fig. 1 *Stages of Concern Model [SoC].*

develop greater understanding of the innovation. Some teachers may progress through the stages of concern more quickly than others. Regardless of how they move, an individual's response to change is, to a certain degree, identifiable and predictable. As a result, the SoC model may be used by inservice facilitators and developers to better organize the inservice program and to help monitor progress of participants. Likewise, teachers participating in the inservice will benefit from an understanding of this model to help them cope with their feelings and those of their colleagues as new ideas and concepts are discovered.

Of further interest to all parties involved in the inservice process is an understanding of the *career stages* of teachers. It is common knowledge that everyone experiences personal changes throughout life. However, these changes are not merely centered around private lives. The change individuals experience through age touches their professional lives as well as their personal lives and manifests itself in clearly identifiable on-the-job behaviors. In her 1989 work *Career Stages of Classroom Teachers*, Steffy identifies and elaborates on a career–stages model based upon the assumption that people are basically good, that they self-actualize and that they become more confident and contributing adults through the work environment. Steffy's model (Figure 2) includes five career stages: anticipatory, expert/master teacher, renewal, withdrawal, and exit. These career stages are not based upon the teacher's age. Rather, career stages are based upon attitudes and behaviors exhibited by the teacher (although there often exists a overlay of age). Steffy's model makes clear that the anticipatory and exit stages are defined by a teacher's entrance into or exit from the system. The other three stages: expert/master, withdrawal and renewal—depend upon the internal motivation and competence level of the teacher. According to Steffy, these individual factors are stimulated by the teacher's working conditions. In an ideal working environment the teacher may never experience the withdrawal stages. Rather, a continual cycle of renewal-expert/master-renewal-expert/master would represent the teacher's professional life (Steffy, p 37).

STAGE	CHARACTERIZED BY
Anticipatory (non-tenured teacher)	-idealism -boundless energy -open to new ideas -creativity -growth oriented
Expert/Master Career Stage	-control (of classroom) -self-actualization -with-it-ness (almost a sixth sense) -evolving (always getting better)
Withdrawal Career Stage	**Initial Withdrawal:** -adequacy (performs job satisfactorily) -quiet (often unnoticeable in group) -follower (have no position of their own) -responsive (receptive to encouragement and motivation) **Persistent Withdrawal:** -critical (of the system, board, administration, etc.) -unresponsive (resist change) -obstructionist -psycho-social problem (difficulty getting along with others; loners; or incessant talkers) **Deep Withdrawal:** -deficient (visibly incompetent) -defensive -difficult
Renewal Career Stage	-reactivated -focused growth -acquiring new skills -dependent (renewal efforts must be supported by the system)
Exit Career Stage (about to leave system)	-commitment shift -nostalgic -need for recognition -judgmental

Figure 2 *Career Stages of Teachers (Steffy, 1989).*

Inservice programs must take into consideration the uniqueness of individual teachers as learners. Teachers engaged in inservice programs are at different stages in their careers and thus have different attitudes towards change. Additionally, teachers' learning styles vary, as do their individual teaching situations. The challenge facing the inservice facilitator, then, is to reach teachers at all levels of the concern model and career stages. In order to accomplish this goal the inservice must be appropriate, process–oriented, and consider the teacher in a humanistic manner.

ORGANIZING THE INSERVICE

As noted above, teachers involved in the inservice process are not only at different career stages but are also at different knowledge/awareness levels regarding ESTE. Joyce and Showers (1980, 1988) distinguish between two purposes of inservice: the "fine tuning" of existing skills and the learning of new skills. Each of these purposes brings different problems, but Joyce and Showers argue that the "fine tuning" is generally easier to achieve. The inservice program, according to Joyce and Showers may be divided into five components or steps:

- presentation of theory,
- modeling or demonstration,
- practice under simulated conditions,
- structured feedback, and
- coaching for application.

The first step, presentation of theory, requires learning about things that are new and is a springboard to further learning and understanding. This step may be accomplished through reading, attending workshops and lectures, or through group inservice sessions. This step essentially involves the development of a knowledge base by answering the "how" questions discussed earlier. The goals of an elementary school technology education inservice at the presentation of theory step would likely be to:

- establish a rationale for ESTE;

- develop an understanding of technology and its application in the elementary school program; and
- provide an overview of the technology systems.

The second step in the model necessitates that new skills be modeled or demonstrated. The teacher learning the new skill will therefore have an opportunity to see it in action. Demonstration lessons and activities, for example, that show the integration of technology in the elementary school curriculum would be an appropriate application of this step. Visitations to schools that have implemented ESTE is an especially valuable way to accomplish this step. Yet another way would be to watch a video of ESTE in action.

The third step, practice under simulated conditions, gives teachers the opportunity to try out new ideas. Using the newly acquired knowledge about technology education, teachers might attempt to write and test technology learning activities or modify existing lessons and class activities to reflect an ESTE approach. One method that has been effective is to have teachers test their newly developed activities on one another. This approach not only gives them a chance to practice but also leads directly into the fourth step, structured feedback.

Structured feedback occurs after the new activity is observed and tested. Teachers participating in the inservice, as mentioned above, can provide valuable criticism for each other as they try out one another's activities or act as participants in a simulated class. Ultimately, the feedback should be provided by a person or persons with expertise in the area. The inservice facilitator or an expert panel can identify the discrete parts of the activity or lesson and offer advice and appropriate correction.

The fifth and final step in the Joyce and Showers model is coaching for application. According to Joyce and Showers's research, coaching resulted in regular and more persistent use of the newly acquired theory or skill. Because most inservice programs are short–term, coaching for application is perhaps the most difficult step to accomplish. Maintaining a connection between the inservice facilitator and teacher would be the ideal approach to coaching. Due to distance and economic factors, however, this may be unrealistic. Another possibility might be to identify someone with expertise in the area, such as a technology education teacher or department chairperson, to provide ongoing assistance. Yet another way to fulfill the coaching for application step is to have teachers involved in the inservice pair up to provide mutual support. While pairing-up does not allow for "expert" feedback, it would provide the moral support and cheerleading often needed when implementing a new concept.

According to Joyce and Showers (1980):

> If any of these components are left out, the impact of training will be weakened in the sense that fewer numbers of people will progress to the transfer level (which is the only level that has significant meaning for school improvement). The most effective training activities, then, will be those that combine theory, modeling, practice, feedback and coaching to application. The knowledge base seems firm enough that we can predict that if those components are in fact combined in inservice programs, we can expect the outcomes to be considerable at all levels (p. 384).

The inservice model presented may be used for ongoing professional development. As shown in Figure 3, the model may be considered circular, commencing with the presentation of theory and proceeding through the remaining four steps. As teachers update or "fine tune" modeling, their practice under simulated conditions and in the classroom and structured feedback will likely be sufficient to result in significant changes.

SUGGESTED INSERVICE CURRICULUM

There is no universal model for an inservice program for ESTE, and rightfully so, since the nature of the inservice is dependent upon such local factors as teacher interest, experience, background and general program support. Programs to provide inservice opportunities ought to be flexible and adapt to meet the needs of teachers, as well as the local educational goals. Thus, inservice programs may range from an overview of technology as a subject

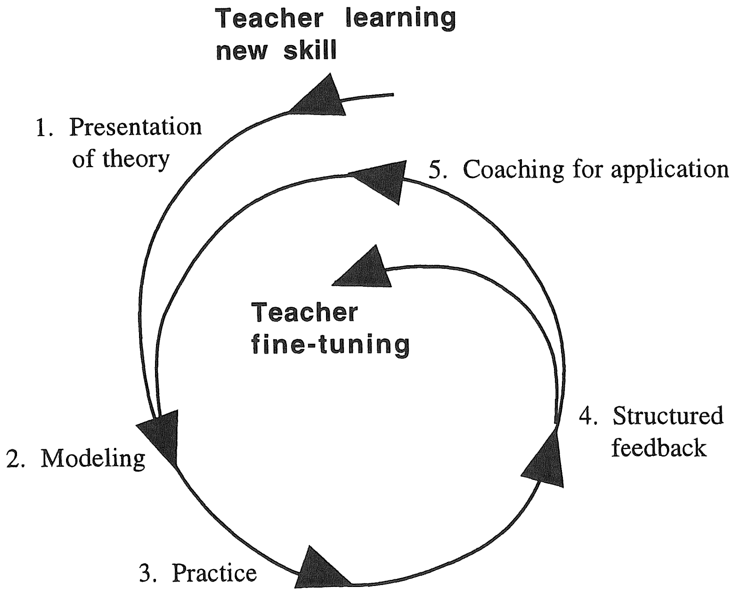

Figure 3 *Inservice Program model. (Joyce & Sanders, 1980; 1988)*

area to experiential workshops in which participants try out activities that are being proposed to workshops that provide opportunities for customized technology education curriculum development.

The diversity of inservice programs is somewhat dependent upon the attitude and commitment of participants, as well as the knowledge and experience of the facilitator. These factors also play a key role in determining what is emphasized during an inservice.

An additional and perhaps more crucial determinant of the type of inservice offered is the time constraint within which the program must fit. Due to budget restrictions and the need for other inservice activities during the school year, the length of the inservice may be quite limited. It is not uncommon for an inservice workshop to last from as little as a half-day to as many as five days. These factors, coupled with the variety and depth of material that could potentially be provided, makes for a daunting task for organizers and facilitators of inservice programs.

While the depth of coverage may vary, the starting point for inservice programs should be the establishment of a teacher's perspective of ESTE. Ascertaining this perspective may best be accomplished through an outlining of technology education and its relationship to the general education curriculum. Educational outcomes must also be identified. Particular emphasis should be placed upon the manner in which a technology program, when infused into the existing curriculum, will provide an alternative to better attain existing educational goals and objectives.

The organization of an inservice should include a rationale for ESTE, information about appropriate technology subject matter, methodology for integrating technology content, and an opportunity to try out and develop technology learning activities. This last point is critical in that it not only provides firsthand experiences but allows for the customization of teacher developed classroom materials. Table 1 shows a suggested inservice program outline and identifies the relationship to the Joyce and Showers inservice model.

PROFESSIONAL ORGANIZATIONS AND SUPPORT

The are many opportunities for elementary school educators to further their knowledge of ESTE. While formal inservice education programs, such as those provided by universities or local education associations are important, they are not the only means of professional development. Professional organizations, private businesses, governmental agencies and professional publications all provide unique opportunities for teachers to increase their understanding of technology education and to remain current. Such outlets also give teachers the opportunity to learn at their own pace and in a manner that may be more effective than structured programs. Significant findings from research about adult learning (Tough, 1979) show that when adults go about learning something naturally (as opposed to being taught something), they are highly self-directing. Additionally, what adults learn on their own initiative they learn more deeply and permanently than what they learn by being taught (Knowles, n.d.). Teachers who

Presentation of ESTE Theory

I. Technology as an area for study
- A. Technology defined
- B. Relationship of science and technology
- C. Technological systems model
- D. Content areas appropriate for elementary school technology education
  - 1. Transportation
  - 2. Energy and matter
  - 3. Mechanisms and machines
  - 4. Structures
  - 5. Communication
  - 6. Biotechnology
- E. Technology and society
  - 1. Impacts
  - 2. Futurology

II. Elementary school technology programs
- A. Curriculum goals
- B. Sequencing instruction
  - 1. Themes
  - 2. Activities
- C. Organization of learning activities

III. Integration of technology with traditional subjects
- A. Science
- B. Mathematics
- C. Language
- D. Reading and Spelling
- E. Social Studies
- F. Music and Art

IV. Methodology for technology activities (Modeling)
- A. Technological method
- B. Developing, using and designing briefs
- C. Design technology
  - 1. Problem solving
  - 2. Invention and innovation
  - 3. Research and development
- D. Documenting work
  - 1. Project portfolios

V. Development of technology learning activities (Practice)
- A. Writing
- B. Testing
- C. Refining

VI. Synthesis (Structured Feedback)
- A. Presentation of developed technology learning activities and/or lessons to the groups

VII. Coaching for application

Table 1 *Suggested Inservice Program For ESTE Utilizing The Joyce And Showers Model.*

avail themselves of the plethora of external support will likely be more accepting of new concepts and embrace ESTE. School administrators should make a concerted effort to give teachers opportunities, support and time for non-structured professional development.

Sources of support

There are many professional organizations on the local, state, national and international levels that provide elementary school teachers interested in technology education opportunities for professional growth. Of these organizations, the International Technology Education Association (ITEA; founded in 1939 as the American Industrial Arts Association) devotes its resources to promoting technology education at all levels. Membership in the ITEA is open to anyone with an interest in technology education.

The ITEA makes available to its membership a broad range of resource materials that can assist the classroom teacher in a variety of ways. Many of the materials are designed to provide background information for the teacher interested in developing curriculum or expanding existing course content. Other materials provided give the teacher practical activities or ideas that can be directly incorporated into the class. Materials of a practical nature include the multi-volume *Resources in Technology*. These booklets are reprints of the "Resources in Technology" section found in the ITEA journal *The Technology Teacher*. The booklets contain information on a wide range of technology topics followed by technology education activities, student quizzes and suggested reference materials. The *Resources in Technology* material is written for classroom use and may be duplicated for dissemination to students. Of particular interest to elementary school teachers is the 9-minute video *Technology is Elementary*. Covering topics such as problem–solving, critical thinking and the interdisciplinary nature of technology in the elementary grades, this video identifies ways ESTE can enhance the curriculum. Also available through the ITEA are informational posters, brochures and other materials promoting technology education.

Another resource available to ITEA members is the *Technology Bank*, a compilation of papers, articles, presentations, technology learning activities, videotapes and related materials. The *Technology Bank* materials are grouped into five categories: Curriculum and Programs, Projects and Activities, Organization and Management, Speeches and Presentations and Special Topics. Examples of ESTE materials available from the *Technology Bank* are identified in Table 2.

Through its journal, *The Technology Teacher* (TTT), ITEA disseminates information to the profession. Issues in TTT cover a broad range of interests and include instructional ideas, classroom activities, program and curriculum articles, product information, book reviews, the Resources in Technology section, Technology Learning Activities (TLAs) and perspectives articles. A subscription to TTT is included in membership to the ITEA. The ITEA also produces a more recent journal, *Technology and Children*, which provides feature articles, program articles, and activities specifically for the elementary grades. This journal is distributed to schools that have become member schools in the ITEA and to other interested individuals. At the time this article was written, however, further distribution plans were not fully established.

The ITEA annual conference attracts elementary school teachers and others from throughout the U.S. and abroad. The conference is held in early spring and different locations throughout the continental United States. More than 100 educational sessions and workshops and 250 educational exhibits attract over 2,600 professionals to the conference. In addition to formal presentations and workshops, practical activities are displayed by classroom teachers during the Technology Festival. Preconference workshops are also available for interested persons. These full-day intensive workshops usually include at least one specifically dealing with ESTE. Other pre-conference workshops, such as "The Integration of Science/Math and Technology" or "Grant Writing for Technology Education," are of general interest. During the four days of the Conference there is ample opportunity for professional interaction with other teachers, college faculty, textbook publishers and exhibitors between sessions and during social functions. The ITEA

Number	Title	Author
89-090	Standards for Elementary School Technology Ed.	E. Savage
92-224	The Whole Language Approach to Technology in UK	Bagshaw/Pitt
91-208	Technology Education Curriculum Standards K-12	S. Barbato
91-177	Elementary School Technology Ed.- A Modular Res. Pkg.	M. Pedras
90-025	Design & Technology in the UK: Moving Towards a Cross Curricular	M. Coleman
90-012	Elementary Technology Course of Study- grades K-6	Los Angeles USD
88-002	What Do Girls and Boys Think of Technology	J. Ratt
92-228	A First-grade Curriculum Guide for Elem. Sch. Dist.	Cranbury
90-162	Technology Education in the Elementary School	DOE/OH
88-043	TE in the Elementary School	DOE/ME
91-194	The Development of an Assessment Framework for Design and Technology for 11-13 Year Olds	R. Ager
91-177	Elementary School Technology Ed.- A Modular Resource Pkg.	M. Pedras
93-325	K-12 Tech/Engineering Educ: It Is World Class	R. Wright
93-305	Tech Day Camps for Elem Children	Extepp/Butler
93-287	Integrated Elementary Technology Education	C. Ortega/R. Ortega
93-308	An Overview of the Ten Sleep School Center for Applied Learning (Video)	L. Miller

Table 2 *Technology Bank Materials [Titles as printed by the ITEA].*

conference provides a stimulating and rewarding professional environment for enrichment and is perhaps the single best opportunity for teachers to gain a wealth of information in a relatively condensed period of time.

Within the ITEA are councils that represent special interest groups. Of particular interest to those interested in technology education for the elementary school is the Technology Education for Children Council (TECC). TECC originated in 1962 as the American Council for Elementary School Industrial Arts. Annual meetings of TECC are held in conjunction with the ITEA annual conference. The Council's purpose, in part, is to "define, stimulate, coordinate, and strive for the ideal form of (technology education) as a vital aspect of education in the elementary school" (ACIATE, 1977, Art. II). To this end, TECC sponsors interest sessions during the ITEA conference, and publishes a newsletter for its membership. Over the years TECC has produced 16 monographs (Table 3) available at a reasonable cost.

#1 Constitution and By-Laws
#2 Directory of Resource People
#3 Schools for Children
#4 Problem Solving & Technology
#5 Developmental Growth of Elementary School Students
#6 Implications of Piagetian Theory
#7 Education of the Handicapped
#8 Industrial Arts in the Elementary School
#9 Establishing and Elementary Industrial Arts Program
#10 Safety for the Elementary School
#11 Technology: The Gifted Student
#12 Reading-Technology Connection
#13 Architecture: Building My World
#14 Language Development in the Elementary School Technology Context
#15 Technology Education for the Elementary School
#16 Technology Activities for the Elementary School

Table 3 *Monographs published by the Technology Education Council for Children.*

In addition to monographs, TECC also disseminates elementary school technology education classroom activity packets and other related materials for teacher use. TECC can be a vital resource for teachers. According to Ray (1979), there was a time when secondary school (technology education) content and methods were transplanted into the elementary school but, because of TECC, more appropriate ends and means have been suggested and demonstrated.

The ITEA may be contacted by writing to 1914 Association Drive, Reston, Virginia. The TECC may be contacted at the same address.

Interest in beginning the development of technological literacy in the early years of a child's education has attracted the attention of government organizations and private business. Vast numbers of materials and inservice opportunities are available, often for free or at low cost, to the practicing teacher. Many activities and lesson plans for ESTE are also available on the internet. Such opportunities are generally publicized in professional journals or through mailings to local and regional education agencies.

The National Aeronautics and Space Administration (NASA) provides a multitude of invaluable educational services to teachers. Many of these services and resources were developed with elementary school teachers' needs in mind. NASA operates Teacher Resource Centers and Laboratories in nine locations throughout the United States. At the Teacher Resource Centers and Laboratories, teachers may use NASA resources and facilities to develop curriculum and classroom activities. The materials available at the Resource Laboratories reflect NASA's research and technology development in areas including astronomy, earth science, aeronautics, mathematics, physical science, and life science. Types of resources at the Resource Laboratories include NASA publications, videotapes, 35mm slides, audio cassettes, filmstrips, lesson plans, reference books, bibliographies, and computer software. Single copies of NASA publications are provided free of charge. NASA provides equipment at the Laboratories for previewing and duplicating audio-visual materials. Educators need only supply blank tapes or film.

Teachers who are not able to visit a Resource Laboratory may contact NASA's Central Operation of Resources for Educators (CORE). CORE facilitates the national and international distribution of NASA produced educational materials. A small fee is charged for this service. (For a catalog and order forms write on school letterhead to: NASA Core, Lorain County Joint Vocational School, 15181 Route 58 South, Oberlin, OH 44074.) NASA materials may also be obtained via the internet.

NASA offers teacher inservice workshops, some of which are offered in cooperation with local universities. Teachers completing such workshops often receive graduate or inservice credits. NASA also offers workshops in cooperation with the ITEA, the National Council of Teachers of Mathematics (NCTM), and the National Science Teachers Association (NSTA). NEWEST (NASA Educational Workshop for Elementary School Teachers), available for elementary teachers, is one such workshop. NEWEST is a two-week workshop held at NASA centers across the U.S. it allows teachers to learn about the latest technologies. Workshop participants attend seminars, visit research and technology facilities, explore NASA projects, work with NASA educational specialists, and review and collect educational materials. Travel expenses, housing and meals are provided. Another form of inservice opportunity offered by NASA is the Education Videoconference Series. Educational agencies may receive these programs using a C-band satellite receiving system or through alternate arrangements. These no–cost programs offer interaction with presenters and free support materials and may be videotaped for future use. Further information about NASA educational materials is available by writing NASA Education Division, Mail Code FEO-2, Washington, DC 20546-0001.

Private industry, businesses and associations are another excellent source of information, resources and inservice opportunities. Associations such as the American Chemical Society, National Science Foundation, American Institute of Physics, Society of the Plastics Industry, National Association for Plastic Container Recovery, Society of Manufacturing Engineers, and others all offer educational support materials. The literally hundreds of organizations and associations, both public and private, may be researched using the *Encyclopedia of Associations*. Many private corporations offer materials for teachers as well. Material available from Phillips Petroleum Company is an example of what companies offer. Phillips offers free videos that teachers may keep permanently and that come complete with instructional guides. Phillips also publishes *Teaching Notes*, a periodical that deals with a range of science and technology topics (contact Teaching Notes, Phillips Petroleum Corporate Relations and Services, 16 B4 Phillips Building, Bartlesville, OK 74004).

SUMMARY

The motivating force behind teachers' efforts to initiate ESTE must be their attitude and desire. To maintain a program that remains current and engaging, a teacher must have the intellectual curiosity necessary to keep up with the rapidly occurring changes within our technological environment. Keeping current may be best accomplished through a variety of activities that include both formal and informal inservice endeavors. Activities that will provide teachers with enriching and mind expanding opportunities include the following.

- Attending seminars, symposia and workshops, such as those sponsored by the International Technology Education Association, National Science Foundation, local education agencies, and other professional organizations.
- Seeking active membership in local, state, and national professional associations that provide technology-education-oriented experiences.
- Reading professional journals and other publications, such as *Technology and Children, The Technology Teacher, Technology Review, Discover, Invention and Technology, Popular Science, The Futurist, Bulletin of Science Technology & Society, NASA Tech Briefs,* and other similar technology publications.

- Enrolling in inservice and graduate courses that deal with technological changes and updates.
- Watching television programs that deal with technology and recording those appropriate for classroom use.
- Contact people within the community who may avail themselves to assist with the technology program and help keep it current.
- Network with colleagues interested in sharing technology materials and curriculum ideas.

Professional development opportunities in ESTE abound. Teachers with little or no experience with ESTE are able to grow to become "experts," if they have the essential ingredients necessary for professional growth—desire and motivation.

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Chapter 12

Review and Synthesis of Research

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In the United States, industrial arts and technology education have been practiced in elementary schools for over 100 years. The traceable record of research about the practice of elementary school technology education (ESTE) is surprisingly limited. This chapter is a review of that research base. It is based upon the initial work of Downs (1974) in which he identifies the existing research base ESTE up to 1974 and incorporates research completed up to the present. In a departure from the format Downs (1974) employed, this chapter is organized in a categorical format, providing the reader topics that have been thoroughly studied, as well as those categories that have not been studied.

ABOUT THE DATABASE

The database for this chapter was drawn from the work of Downs (1974) and a search of two databases, Dissertation Abstracts International (DAI) and Educational Resources Information Center (ERIC). These sources were used because they are available to any researcher in the United States and provide the most comprehensive record of educational research. Studies identified in these databases will be accessible to other researchers who wish to use them. DAI was used because most of the research available in technology education is found in dissertations (Zuga, 1994). The current search revealed that this fact is even more true for studies about ESTE. ERIC was used in order to identify studies published in the general education literature which gets catalogued in this database. While there are many articles about ESTE in the ERIC database, it is important to note that few of them are research-based. Most published articles tend to be prescriptive of idealistic practice or simplistically descriptive of a single project rather than rigorously descriptive, experimental, or evaluative.

In order to define the database, I put limits on the studies that are included in this chapter. First, I restricted the database to studies that were specific to technology education or its historical antecedent, industrial arts. While there were many studies that could be related to technology education, particularly from the science education community, I chose not to include these studies. Studies that integrated technology education, as defined by our profession, with science and other subject matter were included. If, as in the case of several studies, a study originated as science education research and referred to technology as computer use, I did not include the work. Second, I restricted the base to what is available in the United States, particularly through DAI and ERIC. While there is a good deal of interesting and thought-provoking research being conducted in those countries that are further along in implementing universal technology education, educators in the U.S. cannot easily obtain this research through available databases. Some of the international research is being catalogued, but most is not. Therefore, there are a few international studies available in the United States mentioned in this review. Third, I restricted the time periods to include the first database identified by Downs (1974), which begins with a 1931 dissertation and ends in 1993, a year during which no studies were found. While I am sure that there are studies, particularly dissertations prior to 1931, that are about elementary school industrial arts, the record of this work is obscure and finding the research goes beyond the scope of this review. In fact, Downs (1974) included a 1930 dissertation but could report only the title with no information and several of the studies included in this review and identified by Downs (1974) have no abstract information in DAI and are not available through DAI.

Fourth and finally, I restricted the DAI search to abstracts. Collecting all of the dissertations would be a task far too large and expensive to accomplish for the purposes of a review. Therefore, my synthesis is based upon abstracts of dissertations. Professional papers obtained through the ERIC system and available in journals and on microfiche were read entirely because of their accessibility.

I did not restrict the data base as to quality or type of study. Quality is a concern, however, and readers are urged to obtain and read studies that they intend to use. Using abstracts and second source information does not permit an inspection and judgment of quality. With respect to studies, I employed a broad definition of research and included short historical articles, program descriptions and qualitative research as well as the typical form and majority of studies—quantitative research.

As a result of searches employing the above criteria, I identified 85 studies that are included in this chapter. Seventy-two of the studies are dissertations, and 13 of the studies are what I have defined as professional publications. The professional publications were identified through ERIC and are either journal articles or conference papers. Clearly, dissertations make up the majority of the research available on ESTE. Also clear is that, of the few active researchers in technology education in the United States (Zuga, 1994), most are not focusing their research efforts on ESTE.

Given the data base that I identified, I divided the studies into categories in order to survey what has been done with respect to research about ESTE. As I read the abstracts and the studies, I identified categories from the database. These categories are my interpretation of a way to organize the studies, but another researcher may have created a very different set of categories. There are many ways to view this database, and I offer only one in this chapter. It appeared to me as though there were two significant groupings of studies in the following categories: 1) curriculum and 2) student achievement. The majority of the studies (51) were in the curriculum category, while there were 34 studies in the student achievement category. These two initial groupings demonstrate that 60% of the research database is focused on curriculum and 40% of the studies are focused on some selected achievement of students as a result of exposure to technology education. In comparison with the larger pool of technology education research at all grade levels (Zuga, 1994) where curriculum studies dominate all of technology education research, there is a greater focus in the elementary school database on student achievement.

I then broke down the two identified categories into manageable categories of information. The curriculum category was further subdivided into 24 status studies, 22 program descriptions, and

5 historical program descriptions. Almost all of these studies focus on technology education with a few studies focusing on integration. The student achievement category was integrated into 11 other subject matter studies, 7 career education studies, 4 tool use studies, 4 studies of mentally and physically challenged students, and 7 unique studies with no discernible theme. In the student achievement category, only 23 studies focus on unique aspects of technology education, while 11 studies focus on the effect of how exposure to technology education influences achievement in other subject matter.

CURRICULUM

Status studies, program creation and description, and historical description of programs are the three main categories of studies identified in the curriculum category. Of the three groups, status studies comprise the largest and will be discussed first, followed by program descriptions and then historical studies.

Status Studies

At the time that the study was conducted, researchers who studied the status of ESTE looked at a variety of aspects with respect to the state of the art. Fifteen of the studies were focused on public school practices primarily in the United States but also in Europe. In the group of studies related to public schools, four researchers sought to assess teachers' and administrators' attitudes about technology education. Seven studies were focused on teacher education. Most of the research presented as status studies describes a snapshot of school practices with respect to technology education. As these studies are included here, they take on more of an historical value, rather than fulfilling their original purpose of description of current practices.

Public school practices. Three studies conducted in the United States were done in order to describe practices throughout the country. Pinelli and West (1973) surveyed state supervisors and found that 42 of them reported the teaching of industrial arts in the elementary school, with 29 states using federal funds to support those programs. A combination of specialists and classroom teachers were conducting the majority of programs in self-contained classrooms combining both content and method or integrating industrial arts with other subjects as a teaching method. Also in 1973, Nicholls and Young surveyed exemplary technology education programs and found that both skill development and career education were important goals for these programs that placed emphasis upon using activities for the enrichment of other subjects in the hope of increasing academic achievement. These programs were not created with a set of mandatory activities but were designed to be flexible, making sure that there were provisions for student exploration. In 1993, Berlin and Kumar studied the status of science, technology and science (STS) programs through state supervisors' reports. They found that although only 6 states require STS, 9 states recommend and 19 states encourage the study of STS and that most of the programs are kindergarten through twelfth-grade.

Two recent international studies provide a glimpse of technology education practices abroad. In her dissertation, Hutchinson (1988) describes the role of problem-solving in the British technology education program. While she was describing the problem solving process, she did identify and study this process in primary schools. In a detailed qualitative study of the implementation of technology education in Swedish primary schools, Lindblad (1990) characterizes the roles that teachers took on during a school centered implementation of technology education in which there was a deliberate lack of guidance. He interprets that some teachers became pioneers, partisans, spectators, loyal officials, alienated, and independent among several types of roles. Ultimately, most of the implementation resulted in incorporating technology education into existing practices and behaviors.

Several graduate students tried to assess the role of constructional activities in the schools by surveying teachers and former teacher education majors. In 1942, Bicknell studied the development and use of constructional activities in schools by reviewing the European heritage of activities and describing the frequency and purpose of constructional activities. He found that most teachers reported that activities were used to teach other subjects and the purpose of the activity was to develop creativity not to teach about construction. Haws (1947) assesses the emerging role of industrial arts by studying the use that former elementary education students made of the knowledge and skills gained in teacher education preparation. He finds that most of the students had sufficient knowledge but that the lack of time, space, materials, tools and equipment were hindrances to implementation. Haws also notes that supportive administration can remove the obstacles. By using practical activities, Chamberlain (1954) identifies the attitudes of superiors, parental influence and noise as influencing the use of constructional activities in Michigan elementary schools. He also finds that teachers who had more professional education, as well as industrial arts education, were more likely to use constructional activities. VanHerck (1966) continues the line of research about the utilization of constructional activities and finds that elementary school teachers in Missouri were seeking to develop attitudes and creativity with constructional activities. About 80% of the teachers used constructional activities. They also believed that their teacher preparation had been a worthwhile investment. According to Squibb (1968) about 70% of the Ohio elementary school teachers were using constructional activities integrated into other subjects with one third of the teachers reporting three hours of such activity per week. In 1968, Lloyd surveyed University of Missouri-Columbia graduates and corroborated much of the existing research about the utilization of constructional activities with the additional sample of teachers who had not taken preparatory courses in college. He found that those who had taken courses were more able to implement constructional activities.

Two related studies, one by Trapanese (1964) and the other by Swerdlow (1969), sought to describe facilities and equipment, respectively. Many of the previous studies had addressed the lack of equipment, tools and materials. However, Trapanese (1964) found that in New Jersey there were too few specialists, inadequate facilities, poorly designed equipment and inadequate funds for crafts programs. Using another tactic, Swerdlow (1969) identified toys, games and hobby materials available from commercial manufacturers for the purpose of teaching technology education. He found many items available but cautioned that the supplies were not consistent from year to year.

Teacher and administrator attitudes. Four researchers attempted to identify what administrators and teachers believed about technology education. The earliest study, by Williams (1963) surveyed experts in order to identify superior practices. In Texas, Moore (1973) studied school faculty and staff attitudes toward career awareness finding that teachers and administrators would support programs that emphasized career awareness, student self-awareness and involvement of the community. Tuckey (1978) looked at the attitudes of teachers and administrators toward industrial arts and found that they had positive attitudes favoring infusing the activities into the existing curriculum. They also believed that industrial arts contributed toward career education, work skills enhancement, self-imagination and satisfaction. Perusek (1980) studied teachers' beliefs about education in the *Technology for Children* classrooms in New Jersey and found that teachers ranged widely in their beliefs, but they believed that the academic subjects should take up the most curriculum time and that the most prevalent student activities in the classroom involved talking and listening.

Teacher education. From 1953 to 1973, several graduate students conducted studies focused on teacher education with respect to ESTE. These studies were often similar to the status studies with the exception that their purpose was to identify what needed to be addressed in teacher education.

In 1950, Duncan surveyed teachers and found that the more education a teacher had the greater the chance of using constructional activities. He also determined that the activity must support a teaching unit and be simple and successful for students. Scobey added to this body of knowledge in 1952 by determining that teachers had a vague conception of technology education and that they needed more teacher training experiences. Fagan (1954) identified what role and what curriculum was the most common for teaching manipulative activities in colleges, while Robinson (1955) explored the background characteristics of elementary school industrial arts teachers, finding that some had no experience in their area of teaching. In 1963, Low asked California elementary school teachers for recommendations about teacher education and the teachers recommended that at least one industrial arts class be required.

In an attempt to identify what was being taught by universities, Bruce (1964) surveyed the university faculty and found that out of 165 departments, 143 offered elementary school industrial arts courses that were based upon the traditional woods, metals and drawing models of curriculum. Finally, in Nebraska, Blezek (1973 surveyed), with mixed results, teacher educators to determine the extent of implementation of 63 career education concepts.

Program Recommendations

Closely related to the status studies were the studies that had recommendations for curriculum. Research in this category either examined or created elementary school technology education programs. Once again, these studies were divided into those focused on the elementary school (15) and those focused on teacher education (6).

Elementary school The earliest study of curriculum found was Hornbake's dissertation (1939) and, in it, he makes recommendations and provides a rationale for the study of industrial arts in the elementary school. Power (1955) provides recommendations for a "related arts" program in Bloomfield, New Jersey, while, in 1956, Benson created a manual of craft activities for playground leaders and camp counselors. As a result of a government grant, Hoots (1968) developed a course of study for elementary school industrial arts. His program was similar to the program devised by Scobey (1968) in her textbook and provides further evidence of the leadership provided by elementary school technology educators in adopting the technological systems advocated today by technology educators at all levels of schooling. Hoots (1968) recommends studying communication, construction, manufacturing, transportation, power, and service. In 1970, Inaba created an instructional system including text, workbook, transparencies and resource guides for a unit on electronics. In 1978, Duoma studied the implementation of the Technology for Children Program in New Jersey and identified the characteristics in that program that teachers most frequently employed. These characteristics were community involvement, emphasis on children's self-awareness and a child centered curriculum. Based upon the recommendations of experts, Keller (1978) developed a curriculum for elementary school industrial arts.

In the late 1980s and early 1990s, several reports were published documenting the work of a funded project at Virginia Polytechnic Institute. In separate reports, Brusic, Dunlap, Dugger, and LaPorte (1988); Brusic, Dunlap, and Dugger (1990); and Barnes, Wiatt, and Bowen (1990) report on the implementation of the *Mission 21* project. Interestingly, their technology education curriculum recommendations are similar to what Hoots (1968), Scobey (1968) and others in elementary school technology education had been advocating twenty or more years earlier.

Hoping to stimulate industrial arts activities, Kohler (1951) provides teachers with guidebooks that integrated arts activities with reading, science and arithmetic. Simmons (1958) provides a rationale for integration of industrial arts with other subjects in public schools. Continuing this line of research, in independent studies, Griffin, Ljostad and Champion investigate the possibility of integrating industrial arts with science concepts (Champion, 1965; Griffin, 1965) and create a teachers' guide for doing so (Ljostad, 1965). In 1967, as career education goals were being strengthened in the schools, Peel (1968) provided an analysis of mathematics for the purpose of integrating activities related to industrial occupations.

Teacher education Starting in 1949, six graduate student researchers created curricula for teacher education. Robbins (1949) provides a handicraft manual for teachers that details directions for activities. Loats (1950) created a program for the preparation of elementary school teachers in industrial arts and recommended increased inservice education. Brown (1955) conducted a needs assessment to identify the competencies elementary school teachers need in order to teach traditional industrial arts content. Gilbert (1955) created a teacher preparation curriculum based in manufacturing, construction, power, transportation, communication and management with additional recommendations about how the preparation program should be conducted. In a slightly different approach, Kroh (1957) made recommendations for improving the preparation of New York industrial arts teachers with respect to elementary school practices since their license enabled them to teach in elementary schools. As the latest entry into the teacher education curriculum, Leeper (1978) provides an inservice curriculum for elementary school teachers.

History

While many of the studies reviewed above are historical in value today, several studies began as histories and are mostly curriculum based. In 1955, Krumbiegel reviewed "recent" developments in the activity movement in the United States, including such topics as unit work, the project method and experimental evidence in favor of activities. Two other researchers documented the history of industrial arts in the California locations of Long Beach (Genevro, 1966) and Pasadena (Thomas, 1967). Since California schools had a strong commitment to elementary school industrial arts, this documentation of particular programs helps to provide some historical information about the practices in the field. On another path, Harrold (1978) documents the life of Burl Neff Osburn, who provided leadership at Millersville State College, a school that had a strong emphasis on elementary school industrial arts. More recently, Herschbach (1992) provides the field with an interesting history of the kindergarten movement as an activity-based form of instruction that combined sloyd, crafts and activities. Unique to his history, with the exception of Bennet (1937), is the recognition of the role that was played by women educators and reformers.

Curriculum Research Results Given that status studies primarily capture current practice, most of what was reported in these studies is no longer relevant to ESTE practice. For example, the focus on career education in the 1970s may no longer be as important to teachers, since that focus occurred as a result of federal government influence and funding. However, a few ideas about implementation and the difficulty of implementation do have value in both the older and newer studies.

One of the findings with the greatest amount of corroboration is the role of preservice and inservice education. Technology education and experience increases the likelihood of teachers' implementing programs. With respect to implementing programs, it appears as though there are obstacles to the implementation of ESTE that can be alleviated by supportive administration. Some of those obstacles remain consistent with funding, time, facilities, and the like. included on this list.

It also appears that technology education is not accorded subject–matter status and that it is taught in conjunction with other subject matter that is required in elementary school. Its primary purpose appears to be as a motivator for teaching other subjects and to increase creativity, self confidence and self expression.

Even though the pattern of using technology education as method rather than content was clearly established, those researchers who were interested in creating programs persisted, often recommending technology education content. The program descriptions for both public schools and teacher education vary based upon location and date. Most of the information included in them is of historical value. One of the more interesting historical footnotes provided by a look at program recommendations is the clear evidence that elementary school technology educators were often far ahead of their colleagues in implementing a contemporary version of technology education. Clearly Gilbert (1955) and Hoots (1968) demonstrate leadership in implementing change in technology education through the elementary school guidelines.

The historical studies are a mixed bag with too few of them to create a good look at the history of the field. If most of the studies in the curriculum section could be combined, a clearer picture of the history of elementary school technology education begins to emerge. The early but gradual change from traditional industrial arts curriculum and practices to the contemporary curriculum of technological systems with the practice of problem–solving is documented in these studies.

STUDENTS

Researchers focused on students' performance, achievement and attitudes in a variety of ways. One of the first distinctions is that researchers either looked at unique aspects of technology education (23 studies) or the role of technology education in contributing to success in some other subject matter through integration (11 studies). Since the category of studies related to the unique aspects of technology education is the largest, those will be discussed first.

Unique aspects

Historically, career education has been a goal of technology education, and it is the one goal that has been studied the most as a unique aspect of technology education. Following the interest in career education has been an interest in appropriate tools and their use for children, the teaching of technology education to physically and mentally challenged populations, and a mixed group of studies that have no defining theme other than student performance.

Career education As career education grew in popularity among mainstream educators, it became a popular topic of study. Researchers tried to demonstrate that technology education fulfilled this goal. In 1967, Goff set up an experimental program of vocational guidance in an elementary school. He measured an increase in vocational knowledge and aspiration as a result of the program. McLaren (1974) studied the effects of three instructional approaches on students' awareness of the skills needed for an occupation. He used the occupation of carpenter and provides three distinct instructional approaches: reading, drawing, coloring, and displaying work; a demonstration and construction activity; and a visit to a job site. No significant differences are found. Goodness (1977; 1978) tested third-grade students' career awareness after exposure to industrial arts classes and found a significantly higher awareness than students' who were in a control group. In assessing the career education effectiveness of the *Technology for Children* program (T4C) in New Jersey, three studies over a period of three years were conducted. Perkowski (1978) tested sixth-grade students' career awareness as a result of exposure to the program and found that the T4C program tended to indicate support for motivation, career maturity, and reading achievement. McGuire (1979) tested sixth-grade T4C students and found no significant differences between the groups of students, with only a few differences on subsections of the tests. Wardell (1980) also tested sixth-grade students to determine motivation and career maturity and found that exposure to the T4C program did not increase motivation or career maturity. As a group, studies about the effectiveness of technology education for career education purposes are inconclusive.

Tool use Four studies evaluating children's use of tools have been conducted. Hansen (1964) began this line of inquiry by evaluating six tools and a workbench to see if there are significant differences between the body build of fifth and sixth-grade students and their ability to use the tools. There are significant differences in the use of coping saws, hand drills and bit braces. At the same time Bonde (1964) studied first-grade students using tools and recommended that the use of hand drills and planes should be limited and that seven, ten, and 13 ounce claw hammers; 16, 18, and 21 inch panel saws; the wire and rigid frame coping saws; the eight, ten, and 12 inch bit braces; and the 14, 16, and 18 inch sawhorses were usable. Continuing this research, Doutt (1965) evaluated selected tools with second, third, and fourth-grade students. His results were similar to Bonde's. Much later, Trautman (1990) studied the affects of tool size on first and fifth-grade girls' hammering performance. She concluded that the size of hammer made no difference without instruction in use and that instruction should focus on developing proper motor patterns rather than output. These tool studies provide teachers with straightforward information about the selection of appropriate tools for classroom use.

Challenged students Four studies examined various factors relating to the instruction of physically and mentally challenged students in technology education. In 1968, Baugrud explored teachers' professional preparation, instructional approaches and the extent of agreement between experts' recommendations and teachers' practices and found a general agreement between the groups. Oaks (1970) evaluated the effectiveness of a sequence for teaching a psychomotor task to severely mentally-retarded students and finds that the sequencing provided for significant retention. In a similar study, Bender (1971) used a visual method of instruction followed by imitation and finds this method to be effective. Campbell (1977) attempted to determine the effects of activities on the affective, cognitive and psychomotor achievement of learning-disabled children and finds that the program fostered positive gains in reading comprehension, vocabulary, mathematics and psychomotor functioning while stabilizing self-concept.

Other studies

Six researchers attempted to study the teaching of some aspect of technology education. In 1931, Gunther compared manipulative participation in industrial arts to cognitive learning with no results reported. Brudzynski (1966) studied two methods of teaching electricity and magnetism to fifth and sixth-grade children and finds that there was a relationship between students' general achievement scores and inductive or deductive methods of instruction with the lower achieving students doing slightly better with the deductive method and the higher achieving students doing slightly better with the inductive method. In 1969, Palow replicated a Piagetian study about visualization and found that children acquired Euclidean abilities at about age 12 with boys, with higher-ability students doing better. Herrick (1969) compared the industrial technology knowledge base of urban and suburban sixth-grade boys. He found that suburban students were more knowledgeable. With sixth-grade students, Richards (1970) tested two forms of instruction for measurement skills, verbal and verbal-manipulative and found no significant differences. Testing psychomotor performance feedback on performance of fourth- and sixth-grade students, Hurley (1971) determined that viewing a videotape with the aid of a check sheet improved performance. In 1979, Perruso studied the effects of the T4C program on the creativity of fourth-grade children. Using the Torrance Tests of Creative Thinking, she found no differences between scores for all children, boys or girls, regardless of exposure. In a subtest of fluency, she did find an interesting gender relationship: boys with female teachers and girls with male teachers scored slightly higher. In 1982, Zuga conducted a qualitative study of grades two, four and six of a small elementary school in order to determine how students interact with the curriculum as an educational criticism for technology education. She found evidence supporting students' interest and inquiry into technology education topics and provided directions for both curriculum development and further research.

Integration

As researchers learned about elementary school practices, they were taking a cue from the exposure. Common knowledge was that elementary school industrial arts was not provided subject status in the school curriculum and that it was often taught in conjunction with other subject matter in order to meet objectives, such as increasing creativity and self-confidence. This led researchers to study the integration of subject matter. Most of the studies of integration are about the relationship between science and technology. Five out of the 11 studies examine the integration of science and technology education alone, while several other studies incorporate science and technology with other subject matter, such as mathematics and social studies.

Science Electricity and magnetism as science education content serves as the focal point for Gerne (1967), who found that while the teachers and students are favorably disposed to using a circuit board, there is no significant difference between the achievement of students in experimental and control groups. In a similar study using teaching units in electricity and machines to fourth-, fifth-, and sixth-grade students, Pershern (1967) identifies a significant difference in achievement with the experimental groups in the fourth and fifth-grade electricity unit. Once again, teachers and students are more favorably disposed to the experimental units. In 1973, Logan tested a unit on simple machines with third-grade students and found that all student groups who had received the experimental unit with activities had significantly higher test scores than groups that had not. More recently, Brusic (1991) integrated technology with a science unit in order to test students' achievement and curiosity. She found that there is no significant difference in achievement but that there is a difference in curiosity. Using another concept, self-assessment, and a qualitative research method, Rudd and Gunstone (1993) observed a third-grade class during a year long implementation of an integrated science and technology program. They find that this program increased students' ability to assess themselves and that the teacher's role shifted from a dominating instructor to a delegating instructor. These studies do not support the idea of technology education as a method for studying science in order to improve achievement. They do, however, support the idea that the combination of science and technology education increases teacher and student interest in science.

Other subjects In a mixed group based upon integrating other subject matter, several researchers attempt to lend support to the use of technology education as method. Thieme (1965) and Ingram (1966) integrated activity-based units with social studies content. Thieme (1965) found no significant difference in students' achievement either immediately or in the long term after summer vacation. Ingram (1966) had mixed results, also. The students enjoyed the experimental units, which do not prevent learning, as measured by social studies tests. As a side benefit, reading comprehension and study skills improve. Studying achievement in science and mathematics, Downs (1968) identified that directly-related, construction activities relate to students' achievement in science, rather than indirectly relating or providing no construction experience. Kowal (1984) combined technology education with mathematics and social studies to determine the influence of construction activities on students' motivation and locus of control. He finds that construction activities enhanced the motivation of students in mathematics, rather than social studies or traditionally taught mathematics and social studies. Ilott and Ilott (1988) take a qualitative approach to studying the effects of construction activities on the vocabulary and grammar of children in a summer workshop program. They found that using technical language and description increased the complexity of children's use of language. Finally, Peterson, Ridenour, and Somers (1990) tested several methods of measurement instruction with industrial arts students and determined that the line identification method of instruction is superior to the fractional method of instruction. Once again, the research does not support the teaching of technology education in order to improve learning in other subjects, but it does support the idea that technology education increases interest in other school subjects.

Student Research Results

Some of the things that the research on students' achievement reveals is that mentally challenged students can improve skill performance with task sequencing, demonstration and imitation. For students, using a video and a performance checklist can improve performance. It appears as though children's interests are piqued by technology education topics and that when they are in a technology education program for a year they become more independent learners.

One of the overriding messages coming from the studies of student achievement is that experimental or quasi-experimental studies comparing method "A" with method "B" are fraught with difficulties. The most frequent result in these studies show no significant difference between these methods, with there being a few exceptions to that pattern. The studies pertaining to career education and the unique aspects of technology education produce a mixed bag of results.

Even more dismal is the research pertaining to teaching technology units in conjunction with other subject matter in order to improve performance in the other subject matter. Most of the studies of technology education as a method for teaching science produce no significant gains in science knowledge. This result followed suit for other subject matter. However, there is a bright spot in that ESTE tends to increase students' interest in other subjects. In addition, reading comprehension as a skill and not as a subject matter seems to improve after exposure to technology education. This phenomenon was reported in Ingram (1966) and reasons for it are explored in Ilott and Ilott (1988). Also, after participating in a year long program, students may be able to become more independent learners, according to Rudd and Gunstone (1993).

It appears as though the predominant quantitative research method used in these studies has inherent difficulties, while some of the more recent use of qualitative research is effectively identifying new issues with respect to elementary school technology education. In the qualitative research that has been done, explanations of children's interests, the way in which activity may improve language use and the growth of children as learners is explored, probed and explained.

Also it appears that, while studies of status reveal that teachers are more likely to integrate technology education into the curriculum, doing so to teach another subject is not effective. There appears to be enough evidence to suggest that this line of inquiry is not fruitful, with the exception of reading comprehension and language use. Science and technology education seem like such a natural pairing and reading comprehension, a cognitive skill, seems so remote from psychomotor activity that researchers may have overlooked the relationship between cognitive, affective and psychomotor behavior.

SUMMARY

The research base of ESTE is scant and largely about curriculum. Much of the emphasis on curriculum has limited value to current researchers. Most of the curriculum studies of status and program are of historical value to us today, and they are the majority of studies. Curriculum studies show that technology education is not accorded subject matter in schools and serves the purpose of making other subjects more interesting. The studies also show that the implementation of technology education rests upon teachers' previous education and experience and a supportive administrator.

A secondary theme in the research base is student achievement. This theme is problematic in that the results are so contradictory that there is little support for technology education as a result of these studies. Those studies that do focus on student achievement are so few and inconclusive in their combined results that they serve little value. Student achievement in other subjects is not affected by exposure to technology education, yet technology education increases students' interest in other subjects. One wonders what inherent value there is to technology education since it has been studied so infrequently.

At this juncture, one could hope that there is a larger pool of technology education research that could support elementary school efforts, but that is not the case. Reviews of research in technology education at all levels provide the same message for the field: the research base is weak (Zuga, 1994).

There is some promise in the research base for ESTE. Curiously, it comes from new research methods and from abroad. A positive trend in the research base of ESTE is the influence of foreign researchers and their use of qualitative research methods. These researchers are helping to identify new concepts that need to be investigated.

The qualitative studies that have been conducted in Canada, Australia and Sweden are providing new insights into ESTE practice. Questions that need to be addressed—such as the effect that technology education activities have on students, how teachers are grappling with implementing technology education, and how technology education activities cause students to improve language useæare being identified through these studies. Given the nature of the research style and the research database, qualitative work will help researchers begin to construct a body of research and knowledge that has more potential for providing real support and direction for the field. For example, going into the field to test students' achievement in science as a result of exposure to technology education is a shot in the dark compared to going into the field to observe the value and benefit of exposure to technology education, identifying those things that are achieved and then testing their achievement to support the role of technology education in the schools. Beginning to search for the value of technology education will provide the ground for further research and provide researchers a bit more information before testing for significance. Even if the testing for significance never were to happen, the rich information generated from qualitative research would help prepare teachers and be of immediate value.

EPILOGUE: NEEDED RESEARCH

There are a number of questions that need to be addressed with respect to ESTE. Some of them come from hints buried within studies already done, and some of them come from the total absence of research. Some of the major topics that need to be addressed are identifying what the value of technology education is, identifying what benefit students derive from technology education and identifying what can be done to ease the implementation of technology education.

The value of ESTE has not been established beyond tradition or philosophical statements. Unfortunately, neither has any other subject matter, but technology education is in the position of not being a required part of the schools' curriculum. Other countries have an advantage in that some governments have mandated the study of technology education, kindergarten through grade twelve, but that advantage was often gained at the expense of hard work to demonstrate the need for technology education. Research is needed that demonstrates that children need to study technology by assessing their knowledge base and demonstrating inequities in children's access to knowledge about technology by looking at age, gender, socioeconomic status and regionalism, to name a few variables. Research is needed to explore just what students gain from exposure to technology education.

There are several excellent ESTE programs that need to be studied, not only for what is being done, but also for what students are deriving from technology education. Research is needed to establish the value of technology education as distinct from science education. This statement does not mean that ESTE cannot be integrated. It means that the integration should lead to a clear conception of technology as distinct from science, yet demonstrate the relationship with science, mathematics, social studies and other subjects.

For those who are in the process of implementing ESTE, the process of implementation and the interaction and effects with curriculum, teachers, students and administrators has been a topic of interest and study. As teachers begin to struggle with teaching technology education at the elementary school level, their problems with respect to conceptualization of curriculum, integration, and implementation would be researchable topics that will provide teachers and teacher educators with valuable information about how to ease into a new curriculum. Identifying those factors that make the transition to technology education as easy as possible would be helpful.

Science and mathematics educators have been studying students' conceptual knowledge and growth for several years now. This research base could help technology educators not only identify similar concepts that are addressed in technology education and ways to address them but also conduct studies about concepts that are unique to technology education.

Identifying the appropriate content base for technology education is an effort at which technology educators expend a good deal of time. However, this effort is usually directed by people who are interested in the upper grades and have a bias emanating from tradition. Elementary school technology educators need to ask basic questions about content. These questions include: What is important for all students, girls and boys, to know about technology? What is important for first-grade students to know about technology? What are concepts about technology that first-grade students can internalize? These questions should not be a watered down version of the senior high school conceptualization of technology education. Technology education must be designed for children with children's needs and interests in mind.

As a beginning, the above suggestions for research topics could provide the groundwork for further study and support of technology education in elementary schools. Certainly, there are many more topics that need to be addressed. These are a few suggestions and readers are urged to devote some thought to identifying more.

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Summary and Reflections

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Many educators agree that there is a growing need to better prepare students to live and work in a technological age. As several authors in this volume have pointed out, technological goals are increasingly apparent in the literature of technology education and traditional school subjects such as science and math (e.g., Welty in chapter 6, Childress and LaPorte in chapter 3, Todd in chapter 7). How technological goals will be achieved still remains unclear.

Technology educators have addressed this problem during the past 10 to 15 years by transforming many middle school and high school technology education programs. Unfortunately, there is a dearth of research about elementary school technology education (ESTE; see Zuga, chapter 12). The near-absence of ESTE in the United States is problematic for many reasons. First, many children never experience technology education. Technology education's elective status in secondary education means that only some students participate in these programs. Moreover, the lack of a foundation in elementary school means that these students are getting a late start on their technology education. Imagine the progress that could be made if all students possessed basic tool skills, problem-solving abilities and fundamental understandings of technology before they left elementary school. Instead, most students have their first exposure to technology education in middle school. Even then, it is usually a limited exposure for only some students.

Today's high–school graduates are not as well prepared technologically as they could be, and ESTE opportunities may be the missing link. It will remain a missing link unless it is given the attention and resources necessary to bring the problem to the forefront of the technology education profession and the educational community at large. This effort will require the same energy and support as was given other meaningful initiatives during the history of industrial arts and technology education.

This volume is one response to this need. It has been developed to help address this problem by bringing ESTE issues to the forefront and by serving as a useful and scholarly resource for ESTE program development and evaluation. This synthesis of the ideas presented throughout the volume will identify recurrent themes and ideas and offer readers a reflective analysis of this timely topic.

RECURRENT THEMES AND IDEAS

This volume is organized into three major sections. The interrelatedness of technology with traditional subject areas in the elementary school (e.g., math, science, language arts, social studies) is addressed in the first section. ESTE programs in practice, including a thorough analysis of the curriculum planning and evaluation process that is required, is the focus of the second section on implementation. The final section focuses on theory and research related to ESTE. In this section, two authors discuss training programs for elementary school and technology education teachers and another author examines the current research base in the field.

Recurrent themes and observations are found throughout the volume, and they may provide the insight and directives needed to promise reparation of this missing link. These themes and ideas can be categorized into three general areas: 1) the value of technology education 2) techniques for integrating technology education, and 3) barriers to widespread elementary school-level implementation.

THE VALUE OF ESTE

The value of ESTE is addressed in nearly every chapter of this volume, but it is a primary focus of the first chapter by Foster and Kirkwood. They suggest that ESTE may be the answer to meeting students' needs as they grow intellectually, physically and emotionally. Moreover, they provide evidence of the need to begin technology education when students are young. Their chapter sets the stage for the later chapters which consistently reinforce this idea through numerous examples and ideas.

A Unique Contribution

ESTE programs are presented as highly experiential programs which foster students' understanding of their technological world. Many technology educators are proud of their experiential programs and the unique contribution they make to students' lives. Readers of this volume will find numerous examples of programs that are perceived as rewarding experiences for today's youth in the technology-education literature base.

In this volume, several authors introduce and discuss ESTE programs and activities which provide challenging and meaningful opportunities in technology education (e.g., Foster & Kirkwood in chapter 1, Childress & LaPorte in chapter 3, Welty in chapter 6, Todd in chapter 7, Barbato in chapter 8, and Wright & Miller in chapter 9). Unfortunately, the value of these programs is primarily touted through anecdotal comments and observations (especially in the chapters by Foster & Kirkwood, Todd, and Welty) because there have been few experimental or qualitative studies in this area. According to Karen Zuga (chapter 12), there is a some structured research in the field that tries to support this claim of worthiness. However, the research is inconclusive. Hence, Zuga concludes her chapter by suggesting increased research initiatives in this arena. Research-based evidence the unique contribution of ESTE to students' educational outcomes would likely serve as an impetus for greater recognition by the academic community and to more widespread implementation.

Experiential Learning Opportunities

When adults reflect on their elementary and secondary education, they often vividly recall certain events or experiences with considerable clarity. Most adults fondly remember times of excitement and discovery while compiling a leaf collection, performing in a play, observing chickens hatch or sculpting a clay model during their early school years. Special experiences in secondary schools have also left indelible marks. Few adults who had the opportunity to dissect frogs, construct furniture, or build electronic devices in high school have forgotten the joy of accomplishment in these endeavors. These educational experiences not only teach students important skills and concepts but also encourage student motivation and enthusiasm for learning. Few would argue that experiential activities (as opposed to passive ones) are meaningful to learners, especially at the elementary school level. Many authors in this volume describe the perceived benefits of the experiential component of ESTE as a means of enhancing or supporting other subject areas. As one example, Cynthia Szymanski Sunal and Dennis Sunal illustrate numerous ways of integrating ESTE with social studies in chapter 2. They explain how students can experience technology and social studies through ESTE activities in history, geography, economics, psychology and sociology. They conclude their chapter with a profile of an interdisciplinary unit that illustrates how the topics of energy and social studies can be taught in tandem. As another example, two chapters specifically address connections between language arts and technology (Ilott & Ilott in chapter 4 and Kleeberg and Kirkwood in chapter 5). Fred and Helen Ilott detail connections between language and technology by showing how technological experiences provide young learners with meaningful and concrete information in which to promote cognitive and linguistic growth. Kleeberg and Kirkwood show how children's literature serves as a valuable resource for understanding technology.

Robust Experiences

Perhaps there is no greater benefit from well-planned technology education experiences than their inherent robustness in educational settings. In chapter 6, Kenneth Welty explicates nine considerations that should be given to the development of these powerful activities. He describes the importance of designing activities that are conceptually rich, conceptually transparent, contextually authentic, highly experiential, time and cost effective, intrinsically synergistic, developmentally appropriate, pedagogically sound and operationally feasible. His thorough presentation of this planning and evaluation process clearly demonstrates the potential of ESTE to serve as an efficient means with which to organize and synthesize concepts from numerous fields of inquiry in meaningful ways.

TECHNIQUES FOR INTEGRATING TECHNOLOGY EDUCATION

A second recurrent theme in this volume is the integration of ESTE with traditional subject areas. Nearly every author in the first two sections of the book cites the importance and practicality of this approach. Likewise, several authors also point out the uniqueness of the technology content base (e.g., Todd, Welty, and Childress & LaPorte).

ESTE is presented as having numerous links to the traditional core curriculum of math, science, language arts, and social studies. Moreover, these links make it possible to include ESTE in the curriculum without displacing valuable content. If well–planned and articulated, an ESTE program can help to enrich the regular curriculum by providing opportunities for students to learn other content (e.g., math principles, science concepts, historical themes, and writing skills) through concrete, meaningful and authentic technology activities.

Almost three decades ago, a young woman named Mary-Margaret Scobey wrote an extraordinary book for teachers that is, even today, a remarkable tribute to the significant contribution of technological experiences integrated with the traditional elementary school curriculum. Scobey (1968) begins her book, *Teaching Children About Technology,* with this reflection:

> On top of that hill, I could find the peace and quiet to reflect a bit upon the changes man has wrought in his environment. This book is an attempt to describe such reflections. It is designed to help teachers guide young children who will be the leaders in the peace and quiet of the country and also in the teeming bustle of the city. I hope that it may contribute to the increasingly complex task of educating children who must make an effective adjustment to a democratic society and a scientific-technological culture (p. xiv).

Scobey's message, as with many educators today, is to focus upon the consequential importance of meaningful, integrative learning in the elementary school. She believed that ESTE activities can play a significant role in helping to tie the curriculum together and to bring meaning to abstract and often apparently unrelated concepts.

Three chapters in particular help to bring Scobey's philosophy and ideas to life today. In chapter 7, Ronald Todd advocates the design and technology approach as a means of engaging students in practical and realistic problem-solving activities that help them to develop more complex ideas and concepts. The constructivist approach to teaching technology education is addressed by Steven Barbato in chapter 8 and by Miller in chapter 9. Using this integrative teaching approach, the authors describe how their ESTE programs help students to construct their own views and understandings of technology through a variety of learning activities. Wright and Miller discuss their approach in the context of a small, rural school in Wyoming; Barbato describes his approach in terms of a national program that is available schools in the United States and abroad.

Regardless of the teaching approaches used, one constant remains. ESTE activities, when integrated with other subjects, provide an experiential platform upon which schooling can be made more interesting and rewarding to children. Imagine the possibilities if more students, in more schools were able to experience integrated ESTE activities from an early age. Perhaps a greater percentage of students would be more enthusiastic about learning and schooling if they were able to see, early on, how ESTE had practical and meaningful applications in their lives.

BARRIERS TO WIDESPREAD IMPLEMENTATION

Educational reform is underway in American schools. Reformers stress the need for higher standards and a curriculum to prepare students for the information age. There are demands for less emphasis on rote learning and more emphasis on applied skills, especially in problem solving. There is also a considerable demand for more participatory learning wherein students actively engage in meaningful learning activities—not passive educational projects like doing worksheets and completing pages of isolated math problems. Many of the ideas presented in today's reform initiatives can be seen in the technology education programs already established in secondary schools. And, although there is a groundswell of support for expanding these programs into the elementary school, barriers exist that make the establishment of viable technology education programs in American elementary schools seem unattainable. These barriers relate to expertise, facilities, and school culture.

Lack of expertise

The current pool of elementary school teachers has a much stronger preparation and confidence level for teaching language arts than they do science. These educators are generally even less prepared to teach technology. It is safe to say that a large percentage of these educators have never taken a high school or college level technology education course and most have had no preparation in college for planning and implementing an ESTE program. Based on social norms, it is also safe to assume that the primarily female elementary school workforce has had limited life experiences in technical endeavors (e.g., fixing things at home and building models). Hence, there is an expected lack of confidence and expertise in facilitating ESTE activities.

Another factor related to expertise is teachers' misconceptions about technology. A large percentage of elementary school teachers and their administrators have the false notion that technology is already a part of their curricula because they use computers, CD-ROMs and other forms of instructional technologies in their classrooms. There is a great misunderstanding about the difference between ESTE and instructional technology and this common confusion makes the expertise gap especially disconcerting.

If ESTE is to have a foothold in the elementary school, it must be integrated with elementary school teacher's existing curriculum. For various reasons, including budgetary ones, it is unlikely that ESTE specialists will be employed in elementary school schools to provide separate ESTE instruction. Hence, a serious dilemma exists. How likely is it that ESTE will flourish in a school curriculum that doesn't require it *and* that is administered by teachers with little or no ESTE expertise? The obvious answer is disheartening and the lack of easy solutions is likewise disturbing.

The current pool of teachers needs guidance and support. And, in most instances, new elementary school teachers entering the workforce need this same assistance because they continue to graduate from teacher education programs with no background in ESTE. While this fact may be discouraging, it can also present an opportunity. Two authors in this volume (Lewis Kieft in chapter 10 and Barry David in chapter 11) specifically address this concern by focusing on preservice and inservice training programs. Strong arguments are made for a well-planned teacher training program that addresses ESTE methods and philosophy.

Facility constraints

Many elementary school classrooms are ill-equipped to accommodate technological activities. Too many elementary school classrooms inhibit the experiential learning that is crucial to technology education. To illustrate this, consider the typical elementary school classroom. It is often filled with rows or groups of desks. Moreover, many of these desks have slanted tops that make it difficult to keep project materials in place. There is meager storage space, inadequate open (flat) working areas, and a limited number of electrical outlets. Many classrooms do not have running water or sink access and teachers seldom have easy access to the tools and materials they need to do ESTE activities. While it is not necessary to have full-scale technology laboratories and large budgets for materials and supplies in elementary schools, there are still some basic needs that must be met in order for students to have meaningful ESTE experiences. How likely is widespread ESTE implementation if teachers must scavenge for materials, storage space and work areas in their small classrooms? School leaders need to explore new and innovative ways of working through these problems. Childress and LaPorte discuss some options related to this in chapter 3, but there are still many issues yet to be resolved.

School culture

Several factors exist in typical schools which make the implementation of a new, hands-on educational program more difficult. These include such things as rigid purchasing processes, lack of planning time, pressure to prepare students to score well on standardized tests, frustrations of dealing with minutia (i.e., making phone calls, photocopying and attempting to gain computer access), peer pressure to maintain the status quo, and the like. Many teachers and administrators are unlikely to accept another teaching responsibility when the demands on their time are already excessive.

Technology educators must be sensitive to these concerns when they work with school systems to modify their instructional programs to accommodate ESTE. For example, while there is a belief that a good ESTE program at the elementary school level will not increase teaching loads, there are certainly valid concerns as to how the transition will take place.

Many of these obstacles may be overcome as other educational initiatives take hold in schools. These include site-based management, cooperative and collaborative teaching projects, teacher enhancement programs, core curriculum reform, standards development and school improvement team efforts. The role of some of these curriculum trends in advancing the technology education impetus is addressed, in part, by Foster and Kirkwood in the first chapter in this volume.

CONCLUSION

Educators are constantly seeking new and better ways to teach youth. Today, many leaders are calling for educational reform that challenges students to think more and memorize less. They call for schools that promote integrative learning and active, experiential opportunities. School reformists cite the need to develop an informed citizenry of capable consumers who are able to live in, work in and adjust to an increasingly complex technological society. The remarkable fact of the matter is that what was formerly known as industrial arts is the one school program that has, since its inception, been recognized for this experiential, authentic and concrete approach to learning. Yet it still has to find firm roots in the elementary school. The program is now known as technology education, and it *is the missing link* in the elementary school. Unfortunately, most people in decision-making roles are unaware of ESTE and its potential contributions. Their ignorance is partly due to the fact that technology educators have preached to themselves for too long. The time to renew developmental efforts and build bridges to new opportunities is now.

Barriers exist that will make widespread implementation of ESTE troublesome. But difficulty is not a reason to abandon this laudable goal. Technology educators are at the threshold of a momentous opportunity. If there is truly a belief that technology education *can* and *does* make a difference in the lives of children, then now is the time to make this belief known to educators, parents, policy makers, decision-makers and society, as a whole. There is no reason to assume that technology education must continue solely as an elective program in secondary schools. ESTE can be and should be a viable part of the education of all children. If this message is broadcast to more people outside of this field and if the quality of the merchandise is as good as claimed, the prospects can be inspiring indeed.

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Appendix A Characteristics of Technology Activities

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(Portions of this appendix were adapted from Foster, P. N. (1995). Used with kind permission of the publisher.)

When developing a unit plan that includes technology activities, it may be instructive to inspect the activities to ascertain whether they meet the criteria for a technology activity. There is no widely accepted set of such criteria, but one is offered here to illustrate the potential benefits of establishing a rubric for evaluating the degree to which an elementary-school learning activity is a technology activity.

The process is simple: First, the defining characteristics of a technology activity are identified. Second, the activity in question is inspected for evidence of these characteristics. Assuming the analysis shows that some characteristics are present and others missing, the final step is to modify the activity so that it exhibits more of these characteristics.

A suggested list of technology-activity criteria contains eight characteristics: planning, construction, problem solving, feedback, redesign, content, authenticity, and impact consideration. In this view of technology activities, the first five of these characteristics are the most important and should all be present in any technology activity. A weaker activity might not exhibit one of the last three characteristics. A description of each of the criteria follows.

Planning. Although activities which encourage children to experiment with an assortment of materials in response to a challenge are often worthwhile, a technology activity will always involve students in planning out a solution before setting out to realize it. Planning involves not only drawing physical parts before they are constructed, but sequencing operations as well. Just as importantly, students can be made responsible for specifying materials they will need before a project begins.

Construction. A technology activity is constructional. The student changes the forms of materials constructively. In this view, construction is essential to student participation in technology because technology is always constructional.

Problem Solving. Every technology activity has a purpose. In a technology activity, a solution to a problem is designed. The result of the changes students make in the forms of materials must be in response to a specific need or problem. Otherwise the student is being asked to construct aimlessly.

Feedback. In a technology activity, feedback is provided to the student as to the strengths and weaknesses of the solution. Otherwise the student is solving the problem in a vacuum. Ideally, feedback is triggered or generated by the students themselves, such as when they test or measure a product or feature during its development. In some cases, feedback may simply take the form of the teacher evaluating the product while the student is producing it.

Redesign. The opportunity for improving the solution is available to the student in a technology activity. Otherwise the student cannot take advantage of the feedback provided. Therefore, it is necessary to distinguish between feedback which is formative and that which is merely a recounting or a final assessment of the activity. The presence and use of formative feedback implies that the student is given the opportunity to improve his or her solution to the problem based on the feedback received during the activity.

Content. Some general concept related to technology should be reinforced in a technology activity. The activity should be part of an overall sequence designed to introduce students to some area of technology. By the word *content* it is not meant that students will memorize specific facts. But students cannot best consider appropriate solutions nor can they employ the best construction practices without first acquiring knowledge about technology.

Authenticity. A technology activity has practical and authentic qualities. Authenticity, in a Scobeyan sense (Scobey, 1968), is the degree to which an activity mimics a real-life technological process. Ideally, the student is using the same principles that technologists would actually use to solve a problem that they would actually encounter.

Impact Consideration. Because the students should be considering a real-world problem, the impacts of the problem should be investigated as part of a technology activity. This investigation can often seem tangential to the constructional portion of the activity, which underscores the wisdom in considering impacts before beginning construction. Usually, multiple solutions are weighed before students begin constructing the project; this may be the best time to consider the impacts of each possible solution.

In this view, good technology activities contain most or all of these eight components. If one is omitted, a rationale should be considered. For example, an activity designed to give students practice in using a particular tool might not exhibit many of the last three components. The age of the student must be considered as well. For younger schoolchildren, practicality and authenticity add much to the activity. In later years, technology content is considered to be important.

A rubric such as the one below may be designed to quickly identify the degree to which a given activity possesses the desired characteristics.

NAME OF ACTIVITY			
CHARACTERISTIC	**NOT PRESENT** in this activity	**INCLUDED** in this activity	**ESSENTIAL** to this activity
1. PLANNING			
2. CONSTRUCTION			
3. PROBLEM SOLVING			
4. FEEDBACK			
5. REDESIGN			
6. CONTENT			
7. AUTHENTICITY			
8. IMPACT CONSIDERATION			

In this view, characteristics 1 through 5 must all be included in the activity, and at least four should be essential to it. At least two of the other characteristics (6, 7, and 8) should be present as well. Although such a rubric will necessarily be adapted to suit different teaching styles and different views of technology education, it may be useful to the teacher seeking to ensure that classroom learning activities are technology activities as well.

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Appendix B Snapshots from Practice

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The following three cases describe the genuine efforts of teachers to employ elementary school technology education (ESTE) to enrich their curricula. The purpose of these case studies is to describe the thought processes that went into the planning of ESTE activities for upper-elementary school children. These case studies were written to provide authentic examples from elementary school practice that can be used by those who wish to design and implement ESTE activities.

It should be noted that these cases are not presented as examples of exemplary practice. The relative value of these learning activities in elementary school education is left to the reader. The author's intention is that these narratives inspire preservice and inservice teachers to evaluate current practice and exchange divergent points of view, thereby making ESTE possible in an increasing number of schools.

All three cases are based on the work of elementary school teachers who participated in graduate courses or curriculum projects under the direction of the author. They are based on teacher-developed curriculum materials, pilot-test data, notes from teacher interviews, and teachers' reflections on their work. To ensure confidentiality, all names used in the cases are fictitious.

Operation Oil Spill:

A Ounce of Prevention is Worth a Pound of Clean-up

After reviewing her fourth-grade science curriculum guide, Ms. Johnson made a note in her lesson-plan book: she would need to begin a unit on environmental science in just two weeks. In past years, her students had talked about pollution, conducted recycling campaigns, visited the local landfill, and listened to guest speakers from the Department of Natural Resources. Although these were all good activities, Ms. Johnson wanted to do something a little different this year. According to her curriculum guide, she needed to teach her students about pollution and its effects on the water supply, wildlife, and people.

Several weeks earlier, many of Ms. Johnson's students had been disturbed by the news of an oil spill. They were especially troubled by the number of animals that died as a result of the accident. Ms. Johnson felt the spill would provide an excellent context for studying water pollution and the environment.

Ms. Johnson had a few reservations about her new topic because she did not know much about oil spills and how they are cleaned up. She did know that oil and water do not mix. She had much to learn herself, and wondered how she could engage her students in a meaningful learning activity that would enable them to discover the technological complexities and environmental implications of an oil spill.

So she went to the school library to find books on oil spills. If she couldn't come up with a good learning activity, she could always have her students write a report on the subject. No, she thought, not another report—this can be made much more interesting. To her surprise, the library had several trade books on the subject. Even though they were written for children, the books contained an abundance of technical information presented in a straightforward manner. The colorful illustrations featured lots of helpful details.

As she read the books, she learned that millions of tons of oil are spilled every year from transportation accidents. In addition to tanker accidents, large amounts of oil are spilled near refineries from pipeline breaks, tank leakage, and improper loading and unloading procedures.

When oil is spilled in the ocean, the oil floats on the surface of the water until it reaches the shore. When the birds land in the oil, they become covered with it and can't fly. When the birds preen their feathers, oil enters their bodies, poisons their system, and kills them. She learned how fish, shellfish, sea otters, and vegetation all suffer from the toxic effects of oil spills.

As she read further, she discovered a lot of information about the technology used to clean up oil spills. Before a spill can be cleaned up, it must be contained. This process is often accomplished with the aid of long balloon-like fences. These fences, called booms, can only be effective when the ocean is calm. Once the oil is contained, a variety of methods can be used to clean up the spill. One of the more commonly used options is called skimming. Special machines called skimmers are used to scoop up the oil. These machines look and work like giant vacuum cleaners. Absorbent materials are often used in conjunction with the skimmers. These materials act as sponges that soak up the oil and make it easier to clean up.

Another option is to burn the oil in the open water. After as much oil as possible has been removed, special chemicals called dispersants are used to break the oil into tiny droplets. The dispersants spread the remaining oil out over a larger area. The dispersion process helps the oil break down and decompose through natural processes. Special bacteria and fertilizers are sometimes used to help the oil degrade more quickly.

Ms. Johnson's task now was to define the content and goals of the unit. The handful of trade books she reviewed contained a lot more information than she could possibly teach. To help organize her thoughts she wrote a simple outline. She began with a few ideas about why oil is important to people, where some of the major oil deposits are located and how it must be transported from one place to another in order to help people heat their homes and power their automobiles. The next section dealt with how oil is spilled, its effects on plants and animals, and why it has to be cleaned up.

Her last section addressed the technology used to clean up oil spills. She reduced all the possible methods to a simple list of technical processes: containing, skimming, dispersing, and decomposing. After this structure was laid in place, at least two important questions remained.

First, she was not sure of the best way to have her students experience these concepts. Second, what was worth knowing about oil spills? As she debated this over and over in her head, it became clear to her that oil spills were an example of a larger concept.

Pollution is generally an undesirable result of natural (e.g., volcanoes) or technological power generation systems. The old saying "an ounce of prevention is worth a pound of cure" popped into her mind. This bit of wisdom certainly applied to oil spills as well as to things like solid waste management, air pollution from coal burning power plants, and other environmental problems.

As Ms. Johnson stared at her notes, she decided that she wanted her students to experience how difficult it is to clean up oil, especially when it is floating on water. The words *containing, skimming,* and *dispersing* seemed to be the key to designing a realistic learning activity. It became clear to her that the learning activity should to be a small-scale simulation. She decided the activity must be accomplished on the students' desks. She also had a notion that the learning activity should be performed by teams of children. To conserve materials and still have teams she could manage, she decided to divide her class into eight groups of three students.

She made a list of the things she thought she could use to conduct the simulation. The first item on the list was water. The second was a container for the water. She wanted clear, shallow containers with a flat bottom to minimize spillage. She wanted something reasonably large and strong. With a very small budget, the containers had to be very cheap or better yet, free. Hoping something would come to her later, she decided to continue chipping away at her list.

The next logical item was oil. But what kind of oil? Ms. Johnson ruled out motor oil right away because it would be extremely difficult to clean up and dispose of at the end of the learning activity. She settled on vegetable oil, as her students could pour it down the sink in her classroom when they were finished with the learning activity.

Her list included all the basic ingredients required to simulate an oil spill: water, oil and a container. Now she need to turn her attention to identify potential items that could be used to simulate the tools used to clean up oil spills. Since the children's first order of business would be to contain the spill, Ms. Johnson began identifying everyday items that will float on the water and can be used to surround a pool of oil. Large flat rubber bands came to mind, and another option would be to cut openings into foam trays. The trays are very easy to cut and they will float.

The next task was to something that could be used to vacuum or scoop up the oil. She jotted down "paper coffee filters," because she thought the water would pass though the filter while the oil remained on the paper. Kitty litter seemed like a logical choice too. Cotton balls and small sponges were added to the list based on the hope that the oil would remain in the material when the water was squeezed out. Ms. Johnson was the most optimistic about her next entry, a meat baster. Finally, dish soap, the kind that is supposed to break up grease, could be used as a dispersant. It could also be used to wash hands and materials after the learning activity. An extra stack of paper towels also seemed appropriate for clean-up activities.

She still needed to identify an suitable container for the water. The only idea she could come up with was to ask some of the students to bring baking pans to school. But this presented problems of odd sized pans, students remembering to bring them and then cleaning them before they went home. Besides, she felt she had already asked parents too much this school year and she did not want send notes home ask them for another favor.

That morning, a parent had brought the teachers a large coffee cake as a gesture of appreciation. Not only was this a pleasant treat on a Monday morning, it presented a solution to the container problem. The coffee cake was in a large clear plastic pan with a clear snap-on lid. The top and bottom halves of the coffee cake container would provide two teams with a site for their simulated oil spill. The only challenge left was to talk the local bakery out of three more coffee cake containers, preferably clean ones. After school Ms. Johnson tapped the generosity of a local merchant who was more than happy to help. The container crisis was resolved.

With everything laid out on her kitchen table, it was time to try out the simulation. She wanted to tinker enough to be able to anticipate problems, maximize efficiency, determine time requirements, and minimize potential frustrations.

After an entertaining hour and a half of working with various materials, Ms. Johnson had a plastic pan full of tiny droplets of oil. The pan started out with a well defined pool of vegetable oil in a pan of water. The rubber bands and the hollowed-out foam trays worked relatively well containing the oil as long as one did not jar the pan. The foam trays tended to float a little high in the water and some oil managed to sneak underneath the tray. In a burst of inspiration, pipe cleaners where added to the list.

The meat basting tool was clearly the most effective tool for gathering and removing oil from the water. The tool would be a little awkward to handle for her schoolchildren, however, because of its size. Thinking that "less is more" she tried an eye dropper instead. It was more realistic in scale to the oil spill, easier to control, and best of all, eye droppers are relatively cheap.

The sponge made matters worse. The cotton balls worked a little better because they did not have to be used more than once. In contrast, the sponge tended to put as much oil back into the water as it took out. Ms. Johnson noticed that the used cotton balls were very slimy which inspired a new application for them. In addition to using them as a clean up material, they could be used to simulate animals like sea otters and water fowl. A few bits of paper and down feathers could be glued to the cotton balls to given them specific features.

The kitty litter worked as an absorbent agent, but soaked up as much water as it did oil. Ms. Johnson concluded it is probably a great medium for cleaning up oil as long as it is on a dry surface. A plastic spoon had to be used to remove the kitty liter from the pan. Then she discovered that the spoon was a relatively effective tool for scooping up oil, especially when the oil slick was still intact.

After several hours of tinkering, Ms. Johnson had selected all the materials she wanted to use the following morning. Her biggest concern was the potential for a big mess in the classroom. Another concern was whether the students would really experience a new perspective on pollution and technology. As she thought about this, it occurred to her that one way to impress students about the impact of pollution might be to look at it from a economic point of view. She could not help but think that it must be cheaper for petroleum companies to transport oil safely than it is to clean up the oil have a spill. Her earlier thought recurred: an ounce of prevention is worth a pound of cure, and in this case, a ounce of prevention is worth a pound of clean-up.

In a last-minute brainstorm, Ms. Johnson decided to use some of the play money from her classroom to add an economic dimension to the learning activity. More specifically, she decided to give each group a budget and require the students to buy all the materials required to clean up their oil spill.

The next morning everything was laid out on a table at the front of the classroom. As the students filed in for class they began badgering Ms. Johnson about what the materials were there for. It took a little longer than usual to get everyone to take their seat.

Students began raising their hands. What they wanted to know was "what are we going to do today?" Ms. Johnson answered the question with an overview of the simulation. After reviewing the main points they had learned about pollution, she began to explain the roles that each material might play in the simulation. During her description, she tried to associate some of the materials with the real materials that the students saw the day before in a video segment on cleaning up oil spills.

She then explained the monetary aspect of the project. She handed out a price list and a very simple table for recording expenses. She divided the class into groups of three, had the students rearrange their desks into clusters and put a plastic pan on one of the desks at each cluster. Next, she circulated through the room with a pitcher of water and poured about one inch of water in each pan. During a second tour through the room, Ms. Johnson deposited a few ounces of vegetable oil in the center of each pan of water.

After a few words about handling the materials in a manner that would minimize messes, Ms. Johnson announced that the students could begin their clean-up. She had one member from each team, a "materials specialist," come up to the front to purchase materials and keep track of expenses.

Ms. Johnson walked across the front of the room and announced, "another member in each group will be the records keeper. His or her job will be to describe how well your clean-up strategies work. And one person in each group will be a clean-up technician whose job it will be to actually perform the clean-up operation." Ms. Johnson asked each group to count off from one to three and she assigned jobs accordingly.

Eight students approached the desk, play money in hand, to purchase the materials. Each returned to his or her group with a tool that they would use to begin their clean up effort. Ms. Johnson watch her class at work. The teams seemed to be very organized and on task. She listened to the students discuss the variables associated with their clean-up efforts and the nature of the mess they were trying to clean up. Their ideas were surprisingly insightful. They talked about how difficult it was to clean up oil in water. As they contained the oil and tried to remove it, the spills broke up into smaller drops of oil.

Within twenty minutes all the groups had tried most of the potential cleaning materials and were beginning to run out of money. The remaining oil in each pan was now in tiny droplets. A few drops of dish soap caused the oil to spread out toward the perimeter of the pans, but not all of it could be removed.

Ms. Johnson asked her students to put their materials down and turn their attention to the front of the classroom. When all eyes were on Ms. Johnson, she had them report their findings. Most of the groups reported that their oil spill was very difficult to clean up. One group noticed that the more they worked with the oil the more difficult is was to clean up. Ms. Johnson asked the students if that was also one of the problems described in the video. One student said that it was, but in the video it was because of the weather. Another student commented on how it was important to clean up an oil spill as soon as possible because the spill tends to break up and move closer to shore.

Next, Ms. Johnson asked the students which material did the best job containing the oil spill. Several students stated the hollowed-out foam tray worked the best. One student reported that "the big rubber bands worked pretty good." Another student blurted out that none of them really worked and "the oil leaked out everywhere." After the class had a short laugh, Ms Johnson asked which tool or material worked the best for skimming up the oils. Almost all the student endorsed the use of plastic spoons and the eye droppers. The children didn't like the sponges and coffee filters because they tended to disperse the oil too much making it more difficult to clean up.

Several groups reported that they were almost out of money. Ms Johnson pointed out she had more bad news for all the teams. In the spirit of the simulation, she told all students that they were being fined by the Environmental Protection Agency. In addition, a community near the oil spill site had filed a lawsuit requesting compensation for the damages to their beach and the loss of income from their fishing industries. The students protested as though they were being asked to surrender real money. When things started to settle down, one of the students raised her hand. With a tone of seriousness she asked "wouldn't be cheaper to keep oil spills from happening in the first place instead of spreading huge amounts of money cleaning up the mess?" Ms. Johnson smiled. She obviously had achieved one objective.

The discussion continued with ideas about spending money to prevent oil spills or to clean up oil spills. The students felt it would always be "cheaper to keep accidents from happen in the first place." One of the students pointed out the real problem was "it is always cheaper to take chances and if nothing bad happens, you can save a lot of money." Another student pointed out "accidents happen even when you try to prevent them." A third student suggested that the possible damage is too great to take chances with oil. Many of the children expressed ideas about how the welfare of the earth and wildlife should not be measured in monetary terms.

Ms. Johnson turned the discussion toward other forms of pollution. The conversation slowed down dramatically until it touched on solid waste. All the students turned out to be as serious about recycling as they were about cleaning up oil spills. Ms. Johnson concluded the reason the discussion lost momentum was the students did not have many direct experiences with other forms of pollution.

As the activity was winding up, Ms. Johnson reflected on the learning activity. She decided it was worth the trouble. The direct experience with technology had made the children think, discuss and take ownership of the problem and the process of solving it. She wished she could put as much thought and resources into all her learning activities.

As the students poured their nearly clean water down the sink, Ms. Johnson remembered with regret that she forgot to use the cotton balls to simulate the effects of oil on feathers and fur. Then she thought to herself, "ah well, there's always next year."

Pop Can Solar Collectors:

Collecting and Converting Energy from the Sun

Robert Wells, a technology educator, received a call from Dr. Earl Williams, an assistant superintendent of a large suburban school district just outside of Chicago. Williams wanted Wells to participate in his "Scientist-in-Residents" program which would team elementary school science teachers with practicing scientists for one week. Williams hoped that his faculty and the students would benefit from the scientists' expertise. Although Wells was not a scientist, he agreed to "mentor" Mike Chan, an elementary school science teacher at East Elementary School who was teaching an alternative-energy unit.

Dr. Williams said he wanted each student to make and take home a project during the course of the unit. To Wells, this was putting the cart before the horse; he thought the activity—the process—was more important. With only one week to prepare the activity, the need for a relevant project weighed on Wells' mind.

As he planned the activity, Wells decided to focus his attention on solar energy. With a few reference books sprawled across the floor of his office, he created a file on his computer and began with possible goals for the unit. After a full morning of reading, thinking, keyboarding and editing, the following list filled his computer screen.

Upon completion of the energy unit, students will:

- *Understand that the sun is the earth's primary source of energy.*
- *Know that energy is the ability to do work.*
- *Know energy can not be created or destroyed, it can only be converted from one form to another.*
- *Recognize that energy comes in a variety of forms (i.e., chemical, radiant, electrical, thermal, mechanical, nuclear).*
- *Understand that people use technology to convert energy from one form to another.*
- *Recognize that things like wind generators, hydroelectric dams and photovoltaics are energy conversion systems.*
- *Be able to use a simple systems model to describe how common energy conversion systems work (i.e., input form of energy, energy conversion process, output form of energy).*
- *Know people use solar collectors to convert radiant energy (light) from the sun into thermal energy (heat).*

Before he went any further, Wells decided to call Mike Chan a call to solicit his expectations for the upcoming unit. Wells told him he'd like to work on solar energy concepts.

"I like your idea of focusing on solar energy," said Chan. "It ties in with my unit on alternative energy and it sounds like fun. But Dr. Williams is big on public relations. He wants to make sure that the parents and community know that the school district has an innovative math and science program. So we'll need the activity to end with a project each of my 100 students can take home." As Wells hung up the phone, he knew he had to focus his attention on defining the project.

That night Wells began reviewing his curriculum materials. He discovered several variations for a solar hot-dog cooker but none of them seemed quite appropriate. These designs usually work best outdoors, in direct sunlight on a clear and calm day, and cooking the hot dog often becomes the focus of the lesson for students. Although cooking is an interesting application for solar energy, it is not a common application for the technology. Most commercial solar energy conversion systems are designed for heating homes and domestic water. His goal was to teach inside the classroom and focus on energy conversion systems.

In the past, Wells had modest success having students build and test large working solar collectors in his high school technology courses. However all the collectors he had his students construct were relatively expensive to build. Somehow, Wells had to develop a simple solar collector that could be constructed by elementary school students with a few inexpensive materials. Chan said his budget for the project was $50 which meant about 50¢ per student.

Wells tried to think in basic terms about a solar energy collector. All that is really required is a box, some form of glazing, a black absorber surface (preferably metal), and a fluid, typically air or water. This moment of clarity inspired a new goals for unit. Returning to the word processor, Wells added a new item to his series of bullets under the heading

Upon completion of the energy unit, the students will understand that most solar collectors use:

- *an enclosure to capture radiant energy from the sun.*
- *glazing to allow sunlight to enter the enclosure.*
- *an absorber surface to convert radiant energy into thermal energy.*
- *insulation to retain the thermal energy that is generated.*
- *a fluid medium (e.g., air, water) to absorb the thermal energy and carry it to where it is needed.*

What would be the "absorber surface" in a 50¢ solar collector? Within arm's reach, the answer to the question became clear: aluminum soda-pop cans. They are small, metal, can be easily painted black, are very plentiful, and more importantly, are inexpensive.

He had dozens of cans in the recycling bin that could be painted black with very little money, time, or effort.

With the absorber surface identified, materials for the enclosure and the glazing had to be selected. It was time to visit one of Wells' favorite places for inspiration, the local home center.

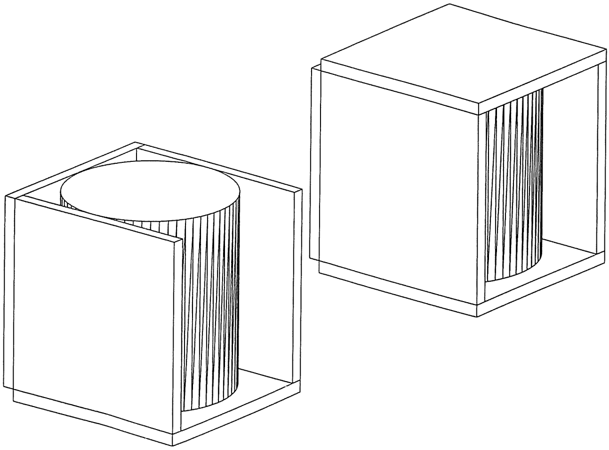
For an enclosure he selected foil-backed, rigid insulation used to sheath houses. He had his choice of sizes and selected ½" thick insulation. He liked it because it could be easily cut with a large T-square and a utility knife, the foil backing would reflect light and it was affordable.

He reasoned that the polyethylene plastic used for vapor retarders and drop cloths would be appropriate glazing material. Pushing a shopping cart, he cruised up and down various isles until he had one 4′ x 8′ sheet of insulation, 12 small rolls of duct tape, a package of utility–knife blades, 200 square feet of plastic drop cloth, two cans of heat-resistant flat black paint, and 6 inexpensive utility lamps.

The total cost was $50—about 50¢ per student. On his way out of the store, Wells made a mental note for one more bulleted item to the list of goals he had on his word processor. It needed to read: *Solar energy is free, but the technology required to collect and convert it into a usable form of energy can be expensive.*

Soon Wells' kitchen table was covered with goodies from the home center. It was time to build a prototype solar collector. He measured a soda can to determine the size of the pieces need to make the basic enclosure. He realized that a classroom-management nightmare could be averted if all the pieces were the same size.

Wells cut out the five uniform pieces of rigid insulation for the top, bottom, sides, and back of a model solar collector. Then he taped the five little rectangles into a simple box that would snugly accommodate a pop can. The task proved to be more difficult than anticipated. He tried to imagine how one set of little hands would hold the various pieces together while another set of little hands tried to apply a strip of duct tape across each seam. Perhaps a block of wood cut to the right size would make a handy mold for positioning the sides and holding them together until they could be taped.



Soon he had a five-sided box taped together with the foil facing the inside to reflect stray light to the pop can. Wells pushed a freshly painted can into the box and made a small hole through the top of the collector directly above the opening in the pop can so a thermometer could be pushed into it. He was sure that the air inside the pop can would heat up quickly when the collector was placed in front of a spot lamp. He taped a piece of the clear plastic across the front of the box and put it to the test.

He found a meat thermometer in his kitchen and stabbed it into the top of the collector and into the pop can. He placed the solar collector on several books and put a heat lamp two feet in front of it. He noted that the thermometer read 68° F. before he turned the light on. Within 30 seconds the thermometer began creeping up. Two minutes later, the air inside of the collector was approaching 100° F. The collector was working.

Wells prepared all the materials he would need and headed out to East Elementary School. Mr. Chan's classroom was the largest in the school. One half of the room had 24 computer stations configured into four rows. The other half looked like a traditional science room. There were 12 large black tables with simple stools for the student to sit on. A mobile chalk board separated the two parts of the room. A relaxed Mike Chan introduced himself and offered to help with the boxes Wells brought.

Wells learned he would see four sections of fourth-graders that day: two in the morning and two in the afternoon. Chan was interested to see an example of the project that the students would be building that day. While he examined the prototype, he described several experiments that he and his students performed in preparation for this project.

One activity involved placing thermometers on different pieces of colored paper. He reported that almost all of the students hypothesized and subsequently proved that the black sheet of paper would get the hottest when placed in the sun. The second experiment involved measuring the temperature of different materials (e.g., sand, iron filings, water, small rocks) placed in different compartments of ice-cube trays that were placed in the sun for several hours.

In preparation for the first class, Wells and Chan began tearing strips of duct tape and draping them off the edge of each table. They also made several neat piles of materials that could be transferred from a counter top to each table during the lesson. The next step in the preparation process was to make a few notes and a drawing on the chalk board. Wells wanted to outline six ideas that he could use to sequence an introduction to the learning activity.

Chan asked, "Do you plan to talk to the kids for a long time? They won't sit still long once they see all these materials laid out for an activity. When I have a hands-on activity prepared, I tell them only what they need to know to perform the activity. We can talk about theory later."

Wells asked Chan to help trim the list a little bit so the students could get to work as soon as possible. Chan did not waste any time taking issue with the first item on the list, the one which read "energy is the ability to do work." He asserted, "The students will remember the words but they will not understand what they really mean. It's just too abstract of a concept for elementary school students." Wells erased the first item and renumbered the rest of the list. Chan reviewed the remaining items, and said that they were all reasonable goals.

Moments after the bell rang, about two dozen bustling and chattering fourth-graders poured into the classroom.

The students took their seats, speculated with their peers about the stranger in the room, and looked curiously at the piles of materials lined up on a side table. Mr. Chan directed their attention to the front of the room. He introduced Mr. Wells whom, he explained, was one of the school district's "Scientists-in-Residence."

Wells said "good morning" to 24 expectant faces. He asked the students to describe what winter was like in Chicago. Several students raised their hands and described the cold weather and the amount of snow that had fallen. Mr. Wells asked the class, "did you know that the sunlight that hits the roof of your house or apartment building on a sunny day contains enough energy to heat your home or apartment building all winter?" Some students looked thoughtful, others seemed bored. Wells asked the students to think of an experience that caused them to notice that sunlight can warm things. Several hands went up right away.

Mr. Wells called on three students, Sandra, Alicia, and Jim. Sandra described getting sun burned on a vacation in Florida during the holidays. Lesha explained how the tile floor in front of her sliding glass door gets warm in the morning when the sun shines. Jim explained how the inside of his family's car gets very hot when it is parked in the mall parking lot for a long time. The students were amused when he demonstrated how he jumped up from the hot seat when he was wearing shorts. Realizing the class discussion was beginning to gain momentum, Wells quickly reviewed the students' evidence that sunlight contains enough energy to heat things.

Wells suggested that these examples were accidents—that people do not usually intend to become sunburned when they sit outdoors, try to heat their floor with sunlight, or collect heat in their car. He moved to the side of the room and asked the students how people heat the air and water in buildings. In response to this question several students volunteered answers that included references to the furnace and hot water heater in their basement. When asked where the heat comes from, several students mentioned burning fuel. They mentioned things like pilot lights, the smell of natural gas, blue flames, and large tanks of oil suggested that most of their home used natural gas and fuel oil for heating purposes. Pointing to his notes on the board, Wells explained how energy resources come in many forms. He said that people use technology such as furnaces, water heaters, and fireplaces to convert energy form one form to another.

As he moved back to the front of the room, Wells asked, "what do we need to collect and convert sunlight into heat?" Most of the students were puzzled. After waiting a few moments, he said "remember Jim's family's car in the mall parking lot? What parts of the car helped it collect and convert sunlight into heat?" Sandra was quick to put her hand up and blurt out "the glass." Wells asked Sandra "what role does the glass play?" She explained the glass allows the sunlight to enter the car just like the sliding glass door off her kitchen allows sunlight to enter her house. Wells wrote "clear glass" on the chalkboard. He then turn back to the class and asked, "what else do we need to collect and convert sunlight into heat?" Vince responded with "you need a box to keep the heat in." Wells agreed, but asked Vince "does it have to be in the shape of a box?" Several students began shaking their heads back and forth, trying to answering the question on Vince's behalf. After a moment of concentration, Vince said "it does not have to be a box, but it can't leak the hot air." Wells turned to the board and wrote the words "sealed enclosure (box)." One student added that the box should be of a dark color.

Wells summarized all the main ideas in the lesson. He drew a sun above the drawing of the box while emphasizing the point that the process begins with the sun. He illustrated rays of sunlight entering the box through the clear plastic and striking the black can. Wells drew a thermometer sticking out of the top of the box to represent heat being produced inside of the box. He closed his summary by asking students "do you think this device would work if we built one?" Malcom quickly asked "is that what the stuff on the counter is for?" Wells smiled and asked Mr. Chan to help distribute the materials.

After a few minutes, all the tables had five rectangles of foam insulation, a piece of clear plastic, numerous strips of duct tape, a wooden block that could be used as a mold, and a black soda can. With only minimal instruction students began working in teams to build their device. Wells and Chan showed students how to use the block of wood to position and tape the foam rectangles together. After working for fifteen minutes, several teams were ready to test their solar collectors.

Wells demonstrated how they should position their collectors about two feet from the lamps which represented the sun. He held up one of the oven thermometers and announced he or Mr. Chan would install it through the top of their collector. He then held up a lab sheet that featured graph lines and several questions. He told the students that one member in each team needed to watch the clock, another member of the team should read the thermometer, and one should plot the temperature on the graph. Wells emphasized the need to take and record temperature readings every 30 seconds. Once the thermometer was installed, the students were told that they could plug in their lamps and begin testing.

The students immediately began to enthusiastically monitor the time, read their thermometers, and plotted points on their graph. The little collectors were working as well in the classroom as they did on Wells' kitchen table. Students were plotting temperatures over 100°F within a few minutes and were completing the lab quickly.

As teams finished, they began to pursue their own ideas. One group moved their collector about a foot closer to the spot lamp in a effort to increase the temperature of their solar collector. The smell of paint and singed foam suggested they were experiencing success.

He gave each group enough materials so that all students could make their own collectors—Dr. Williams should be pleased. Another group asked for two extra pieces of foil-backed insulation. Wells asked what they plan to do with the extra materials but all they would tell him was they wanted to try something. Wells gave them two more rectangles of foil-backed insulation and made a mental note to check on that group in a few minutes.

After making one tour around the room, Wells discovered the group used the extra pieces of insulation to tape a reflector to each side of their collector to increase the amount of light entering the device. When asked what inspired the modification, one of the girls said the idea came from the reflector her big sister uses to tan her face in the summer.

Two groups jointed forces to pool their resources to see what would happen if they used two lights instead of one. Throughout the room students were conducting *ad hoc* experiments that explored the relationship between light, time, and heat in the context of a solar energy system.

A few minutes before the end of the period, Wells asked students to finish what their were doing, turn off their spot lamps, and look to the front of the room. After a little coaxing, most of the students were ready for a modest debriefing. The two teachers asked the students to share their discoveries. Several students recounted how the temperature of their collector increased slowly and then leveled off. In fact, all the graphs showed similar findings. Other students described how they managed to increase the temperature by increasing the amount of light entering the collector (e.g., moving the collector closer to the lamp, using more lamps, using reflector to "bounce" more light into the collector). The students were still sharing ideas when the bell rang and they had to go back to their regular classroom.

Wells and Chan happily agreed that the lesson progressed well and they prepared for the next group of students. Chan also expressed his appreciation for the amount of time and work Wells had invested in the learning activity.

After a long pause, Chan asked, "You don't think Dr. Williams expects me to do this kind of thing on a regular basis, do you?"

WKID Radio:

Informing, Entertaining and Persuading the Public

The next chapter in Donna Flynn's fifth-grade science text was on communication. In the past, this had been one of the driest units in her curriculum. She tried to show at least one film and discuss the various ways people communicate with one another, but she never felt like she'd realized the unit's potential. It was a very rich topic and she knew telephones, radio and television played an important role in her students' lives. Somehow she needed to find a way to make this unit more interesting.

Mrs. Flynn switched on her car radio as she began her short drive home from school. While waiting at a stoplight, she listened to David Richards, a local disk jockey. She could not help but envy him—after all, he had direct access to a communication technology that her students would find fascinating. Too bad there isn't money for a field trip to the radio station. Then she thought, maybe one of the radio personalities would be willing to come to her class and talk to the students about radio and how it works.

The minute she got home, she phoned the studio, and David Richards, who was still on the air, answered. Their conversation was short, but he agreed to be a guest speaker during the following week as long at he could do it before his shift began at the radio station. Mrs. Flynn called back to arrange a time. As it turned out, Richards had made several presentations at other elementary schools. He said it was "lots of fun" talking to the kids who listen to him on the radio.

The students were excited when David Richards came to their class to talk to them about radio. He thanked Mrs. Flynn for the opportunity to be in the classroom and said he always enjoyed meeting his listeners. He asked the class how many of them listen to his show after school. About three quarters of the students' hands went up in the air. Richards was impressed. He said, "listeners are the most important people to a radio station. My work doesn't matter if no one is listening."

He asked the class "how do you think my radio station makes money?" The class was silent—no one volunteered. Richards scanned the room and said "one of the nice things about radio is it is free. You don't have to pay money to listen to the radio. All you have to do is turn on your radio and we are there to entertain you and keep you informed. But, where do you think the money comes from to pay my salary and pay the bills at the radio station?" One student raised his hand and answered, "you make money from advertising." Richards said "yes," and he repeated, "radio stations make money by selling time.

"To make money, the radio station sells small slices of time to businesses in the community who want to tell you about their products or services. We call these slices 'advertising spots.' The people who buy our spots are hoping that you will buy their products or services. If no one is listening to our radio station, our advertising spots are not worth anything. But if lots of people listen to our station, our advertising time is worth a lot of money."

Mr. Richards summarized his main points. "Basically, my radio station provides two kinds of services. First, we entertain and inform our listeners for free. Second, we promote products and services for our advertising clients for money." A hand went up in the front of the room. Richards called on Janet, who asked, "how much does it cost to buy time on your radio station?" Richard's answer was a little vague. He replied, "it depends on the time slot. A lot of people listen to the radio before work and school. Another important time of day is when people are driving home from work and when you listen to me after school. Advertising time before and after work is more expensive than advertising time when most people are asleep."

Richards could sense that his answer was inadequate as soon as he made eye contact with Janet and several other students who were waiting for a simple dollar amount. "OK," he said, "thirty seconds of time before nine o'clock on a weekday morning will cost about $20." The students looked at each other. Twenty dollars wasn't a lot of money. Sensing that he did not impress the students, Mr. Richards pointed out that one hour of radio time might include dozens of advertisements and that his radio station was making hundreds of dollars per hour from advertising. The class looked more interested.

Richards turned to the board and drew a large circle. At the top of the circle he drew a small line straight up and labeled it "1 hour." He drew a second line at the 3 o'clock position and labeled it 15 minutes. At the bottom of the circle, or the 6 o'clock position, he drew a third line and labeled it 30 minutes. He drew the last line at the 9 o'clock position and labeled it 45 minutes. He turned to the class and said "this is what we call in the radio business a program clock. We use a chart like this to plan every hour of radio programming." While pointing to the top of the chart, he said "let's say we program news at the top of the hour and the first few news stories will take three minutes to announce on the air." Mr. Richards drew a line from the center of the circle to the top of circle. He then drew a second line from the center of the circle to the right of the first line forming the first triangular slice in the pie. "Now, let's say it is time for something different, so let's put in two advertising spots for 30 seconds each." He formed two more sliver-like segments in the pie chart. "After playing these two ads let's return to the news, but this time let's do sports and the weather. After the weather, let's play a couple of songs that take about three minutes each." Richards turned back to the board and drew in several more narrow segments. In no time at all he had laid out over fifteen minutes of programming to include news, weather, sports, advertising, music, and friendly conversation.

Mrs. Flynn found the presentation fascinating—things were going very smoothly. She was pleased with how well he was reinforcing the fact that people use math on a daily basis out side of school. She enjoyed the idea that pie charts played such an integral role in radio programming. That would come in handy for a math exercise, she thought. From the back of the room, Mrs. Flynn took advantage of a pause in the presentation to try to redirect the conversation to something related to science and technology. "Thank you, Mr. Richards for showing us how you plan a radio program. Could you tell us a little bit about how a radio station works? For example, could you tell us how your voice gets from the radio station to the radios in our homes?"

As he organized his thoughts, Richards described his studio at the radio station. He explained how the microphone in the his studio converts his voice into an electronic signal. He also described how the how the turntables, CD players, and tape cartridge machines also produce electronic signals that can be transmitted. He described how the electronic signal has a pattern that represents a pattern of sound waves that somebody creates with their voice or a musical instrument.

As Richards was discussing the transmission of signals, FCC-assigned frequencies, and the like, he realized that many of the students were having difficulty following him. He would have to keep this explanations simple. Instead of directly explaining modulation, he said, "the signal that represents my voice and the music is put on top of the frequency that is assigned to our radio station by the government. When you adjust your dial to 95.5 you get the frequency that carries my voice. Inside your radio there are electronic circuits that separate the weaker signals representing my voice and the music from the strong signal that carried it to your radio. The speaker inside of the radio converts the signals representing my voice and the music back into sound."

James had a question, and he asked it. "How does the music and your voice travel through the air?" Richards' simple explanation apparently had missed the mark. How do you explain the magic of radio to a class of fifth-graders? He tried again. "Radio waves travel through the air a lot like light waves. They travel very fast and you can not see them."

Mrs. Flynn did not know how Mr. Richards was going to explain radio in any more detail without getting into electromagnetic wave theory and modulation. Although she had read about both of these concepts in the textbook, she had to admit she did not fully understand the ideas herself.

She decided to rescue Richards by re-directing the discussion. "Can we hear a few questions from some of you who have not had a chance?" Several hands went up and Mrs. Flynn called on them one at a time.

As they questioned Richards, the students learned that he was nervous the first time on the air, and that he usually didn't get to pick the songs he played. After a few more questions, Mrs. Flynn announced it was time to thank Mr. Richards for coming to the class and talking to them about radio. Richards thanked the class for inviting him to visit their class and reminded all of them to listen to him after school.

As Mrs. Flynn escorted her class to the gym, she reflected on Richards' presentation. Things went very smoothly and he did not talk to much over the kid's heads. Radio was proving to be a richer topic than she had first suspected. The longer she thought about it the richer it became. Some of the more salient themes in her mind were public speaking, pie charting, current events, persuasive writing, creative writing, basic economics, and types of music.

Soon she found herself trying to figure out how she was going to follow Richards' presentation with an appropriate learning activity the next day. After dropping off her class at the gym, Mrs. Flynn went to the teachers' lounge where she called a neighbor who taught at the nearby university. She enthusiastically recounted to him the day's events, reviewed the rich interdisciplinary potential of using radio as a theme, and presented her current obstacle to developing a meaningful learning activity—what activity could she do to follow Richards' talk? She knew she wanted her students to experience broadcasting a radio program. After a bit of brainstorming, her friend proposed having her students develop and record a mock radio program into a tape recorder. Although this was a reasonable suggestion, Mrs. Flynn wanted her students to actually transmit a radio signal. They continued brainstorming. The stream of ideas included using a baby monitor, a wireless intercom system, and a wireless microphone for a public address system. The baby monitor was a good idea, but it would only have one transmitter and one receiver. Plus, baby monitors tend to look childish and are relatively expensive. Mrs. Flynn needed something cheaper—something she could use to engage her whole class in the learning activity.

Suddenly inspired, her friend thought of a solution to the problem. "What about a hand-held toy wireless microphone like the ones that they use to advertise on television around the holidays." Mrs. Flynn asked "do you mean 'Mr. Microphone?' Do you think they still make those things?" The idea seem worth pursuing. After all, a toy wireless microphone had to be cheaper and more fun to use than a baby monitor. It had only one transmitter, but potentially had many receivers. Best of all, her kids could hold the microphone and become real radio announcers or actors. She thanked her friend for the ideas and promised to let him know how the unit turned out.

She had time to call a toy store and an electronics store. To her relief, both had several wireless microphones in stock. They were all basically hand-held microphones that can be adjusted to transmit a FM signal to an open frequency on a portable radio. Most of them claim to be able to broadcast a signal about 25 feet away. Best of all, most of them were less than ten dollars. After visiting the stores, Mrs. Flynn purchased a wireless microphone.

Returning home, she tinkered with the radio on her kitchen counter. She found an open area on the FM dial around 92.5 megahertz. Next she installed two AA batteries into one of the wireless microphones and turned it on. After reviewing the instructions for a second time, she inserted a small plastic screw driver into a hole on the microphone. She began saying "Testing 1, 2, 3 over and over while turning the tiny screwdriver. All of a sudden she heard her voice coming from her kitchen radio. "Testing 1, 2, 3. Testing 1, 2, 3." She heard herself broadcasting, "this silly thing works!"

Now that the technical aspect of the learning activity was resolved, she needed to plan the logistics of the project that she was going to give her students the following day. She didn't want to dedicate more than five more class periods to the activity. She could divide her class into six teams comprised of four students each. Each team would be required to develop and broadcast a ten-minute radio program. Then it occurred to her that it would probably take two forty-minute periods just to rotate each team behind the microphone. That would leave three class periods for planning and developing a radio program.

The only way she could stay on schedule was with the cooperation of Mrs. Jones, who taught social studies to her students, and Mrs. Burton who taught music twice a week. With a little luck Mrs. Jones would be willing to teach current events in the context of broadcasting the news. Furthermore, maybe Mrs. Burton could be talked into helping the students select appropriate music for their radio programs. Things were coming together even though there were still a few loose ends.

Before school began, Mrs. Flynn talked to Mrs. Jones and Mrs. Burton about the learning activity. As it turned out they both liked the idea and felt they could work the project into their plans for the next few days. Mrs. Jones pointed out she is always teaching current events and she would be happy to place a greater emphasis on it this week. Mrs. Burton said she had several lessons planned for next month regarding the different types of music but she could move them up if it would help the project.

Mrs. Flynn next stop was the copy machine where she could run off copies of her new assignment which she affectionately titled

"WKID Radio." The handout announced that each student, along with three classmates, was granted a radio broadcasting license from the FCC, (short for Flynn's Communication Commission). Their new station's call letters are WKID. In preparation for going on the air, each team would work together to prepare a 10-minute program. Their radio programming was to include news, weather, sports, music, and advertising. To get full credit for the project each team needed to develop a program clock like the one Mr. Richards drew on the board. They would also have to write their own news stories, commercials, and advertisements. Lastly, they would have to pick out music for each advertising spot based on the target audience of their advertising client.

Each team received a list of advertising clients. Most of them were large businesses in town. One group was assigned a grain elevator, truck stop, and farm implement dealer. Another group was given a fine clothing store, an expensive restaurant, and a large bookstore. Each group of students had a different list of clients.

During language arts, Mrs. Flynn helped the students write advertisements for their three clients. She encouraged her students to be creative and persuasive. She also required the students to take turns reading their advertisements to each other as though they were reading them on the air. The classroom became a little noisier than usual with role playing and ideas being exchanged.

Mrs. Jones, the social-studies teacher, gave the students copies of stories in the newspaper. They practiced identifying the main ideas in each story and tried to write summaries suitable for a radio broadcast. Mrs. Jones also had the students listen to the news on the radio. It did not take long for the students to notice that news stories on the radio were much shorter than the ones in the newspaper. Mrs. Jones pointed out that they still included information that followed the themes of <u>w</u>ho, <u>w</u>hat, <u>w</u>hen, and <u>w</u>here.

During music class, Mrs. Burton asked the students what were the basic kinds of music. The answers caught her by surprise. As far as the students were concerned, there were only three kinds of music: heavy metal, rap, and country music. Mrs. Burton set out to expand the students' awareness of other types of music. She tried to help students realize that some forms of music are old while others are new, and that music can reflect the culture of a group of people. The students listened to examples of classical music, jazz, big band, early rock and roll, popular music, and country music.

Three days of preparation went by very quickly. All the students sat anxiously at their desks waiting for their turn to broadcast. Their desks were grouped together in clusters of four. Each cluster featured a portable radio brought from home to support the learning activity. Each student had a copy of their portion of the script. Mrs. Flynn had set up a large movie screen in front of her desk.

The first team was asked to go behind the screen and broadcast their radio program. It took the students almost two minutes to get organized. They decided who should be first, based on their program clock. They checked to make sure their first song was ready to go on the cassette player. As soon as Mrs. Flynn could see they were ready, she asked the rest of the class to turn on the radios at their desks. Mrs. Flynn asked one of her students for the microphone. She turned it on and began to say "testing 1, 2, 3; testing 1, 2, 3." Soon there was giggling coming from every cluster of desks. She circulated throughout the room listening for her own voice saying "testing 1, 2, 3." The students made minor adjustment to their radio dials. Mrs. Flynn returned to the front of the classroom and gave the microphone back to the students and said "you may begin."

The students stared at the white screen at the front of the room waiting for something to happen. After a little rustling of papers behind the screen, a voice came across all the radios in the room. "GOOD MORNING MIDDLETON ELEMENTARY SCHOOL!" The whole class laughed as the first broadcast got off to a good start.

Each group took their turn broadcasting their radio programs. Most were unique and creative. The students clearly put a lot of thought into their news stories and advertisements. The only real flaw in their programs was an occasional chuckle from time to time. The only time the students listening to the broadcast looked the least bit bored with when their classmates were playing familiar music. The rest of the time the students appeared to be extremely attentive, especially when an advertisement was on the air.

At the end of the lesson, Mrs. Flynn was exhausted and the students were excited. She was thankful for the fact that lunch and recess were next.

As the students gathered their materials to leave, Mrs. Flynn reflected on the activity. The students had accomplished most of the goals she had developed weeks ago. They learned science principles of communication through a technology activity. Beyond those original goals, she realized they had learned to develop pie charts–the graphing she would have taught in math, they had written creative and persuasive stories, they had studied current events and learned about and used different types of music. Not bad, she thought. She was going to listen to radio a little differently from now on. And so would her WKIDs.

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