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ABSTRACT

The 1982 Yearbook of the Association for the Education of Teachers in Science (AETS) is the second in a series of three AETS yearbooks in which Ralph Tyler's 1949 curriculum rationale is used to analyze science curriculum. This publication is focused on the secondary school science curriculum (the 1981 yearbook was concerned with teaching science to middle school students). The 1982 Yearbook is divided into three major sections. Section I contains an examination of Tyler's model as it relates to the current status of science education, which is also discussed in this section. Section II contains six chapters whose authors have used Tyler's model to examine specific aspects of the science curriculum: scientific literacy, problem solving, student motivation, social and political factors affecting the science curriculum, and changing instructional practice, as well as implications for continuing education for science educators. (PB)

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# 1982 AETS YEARBOOK

Edited by

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## AN ANALYSIS OF THE SECONDARY SCHOOL SCIENCE CURRICULUM AND DIRECTIONS FOR ACTION IN THE 1980'S

ERIC Clearinghouse for Science, Mathematics
and Environmental Education
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Association for the Education of
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ERIC/SMEAC and AETS are currently cooperating on a tenth publication. We invite your comments and suggestions on this series.

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# Preface

The 1982 AETS Yearbook represents the second in a series of three successive AETS Yearbooks in which the science curriculum is analyzed using Ralph Tyler's 1949 rationale. In the 1981 Yearbook, edited by Dan Ochs, the focal point was science in the middle school. The present volume addresses science curriculum at the secondary level. Tyler's rationale will be applied at the elementary level in the 1983 AETS Yearbook.

Readers may wonder why a discourse published more than 30 years ago is employed to analyze and interpret science curriculum in the 1980's. Surely recent developments in curriculum theory should have rendered Tyler's rationale obsolete and relegated it to the antique shelf. The Tyler rationale, however, holds up well under the test of time because it possesses parsimony, a quality highly valued in science, and it represents a clear lens or looking glass through which curriculum may be studied. The simplicity, elegance, and clarity of Tyler's rationale are illustrated in four fundamental questions to be answered when analyzing and interpreting curriculum:

1. What educational purposes should the school seek to attain?
2. How can learning experiences be selected which are likely to attain these objectives?
3. How can learning experiences be effectively organized?
4. How can we determine whether these purposes are being attained? (Tyler, 1949, p. 1; see Reference, p. 20)

Yet there is danger in Tyler's questions because, contrary to expectations, the answers do not possess elegance and simplicity. They do, however, retain clarity and reflect the complex nature of curriculum.

Science curriculum is not only complex, it changes. Many factors affect science curriculum, individually in one manner and together in still other ways. In the 33 years since Tyler's work appeared, the science curriculum has been radically modified at all levels. The Sputnik crisis and the period of curriculum development and change that Sputnik preciptated are history. But the preponderance of evidence suggests that the science education community presently faces a more serious emergency. Unlike the launching of Sputnik, however, no single event has yet to focus the attention of the general public and governmental leaders.

The purpose of this volume is to describe, analyze, and interpret the current emergency, and to suggest possible directions for action as they pertain to secondary science curriculum. Tyler's rationale is an historical yet valid instrument for such an endeavor.

One aspect of dealing with the current crisis includes the establishment of a better dialog between the university community in science education and science teachers, department chairpersons, curriculum supervisors, and top-level school administrators. To that end, the Yearbook is addressed to a broad, general audience, including primarily science teachers, department chairpersons, curriculum supervisors, building and district administrators, and, lastly, college and university-level science educators.

The present yearbook is organized in three major sections. Part I includes two chapters. In Chapter 1, Louis Rubin delineates Tyler's model and establishes its relevance to the current scene and potential revisions in science education. In Chapter 2, Robert Yager describes the current status of science education, beginning with an historical perspective, then analyzing current accomplishments and needs, and finally describing a new direction.

Part II includes six chapters. Each author focuses Tyler's lens of analysis on specific aspects of the science curriculum. Peter Rubba delineates citizen scientific literacy as the goal for science education in the 1980's. Carl Berger uses teaching, learning, and problem-solving styles to show why different curricula and instruction work differently for individual teachers. Paul Beisenherz discusses student motivation. Dudley Herron analyzes social and political factors which affect the curriculum. Hans Andersen outlines a multidimensional curriculum model plus a strategy for changing instructional practice. Dennis Prisk and John Staver synthesize the individual discussions of all chapter authors within the context of continuing education for science educators.

The final section consists of reactions from the science teaching community. Because the volume addresses principally science teachers and their immediate superiors, the majority of the reactions come from the classroom teachers, science department chairpersons, and science curriculum supervisors. Two reactions are contributed by university-level science educators.

It is the intent that the present volume serve as "a point of departure," to quote Tyler. Issues fundamental to the current crisis in science education are discussed and suggestions for change are presented. Each reader's task, however, has only begun at this volume's end. If readers are stimulated to follow up on issues and suggestions discussed on these pages, then the Yearbook will have served its purpose.

John R. Staver

# ACKNOWLEDGEMENTS

I wish to express my most sincere thanks to Hans Andersen. As president of AETS, he provided me the opportunity to organize and edit the present volume. His counsel and encouragement proved most valuable throughout the endeavor. I also wish to express my sincere appreciation for the contribution of each chapter author and reactor. They have succeeded admirably at the appointed task, and the immediate and long-term value that the yearbook possesses is due to the diligence of each contributor. And, of course, no project would ever be completed without the assistance of an able secretarial staff. Rose Jusko, Lynn Casey, and Mamie Gray are due special thanks, for their assistance in typing reference lists, manuscripts, letters, etc.

John R. Staver, Editor

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Dr. Andersen's career in science education has included activity in local, state, and national professional organizations. He has served on the board of directors of NSTA, AETS, and the Hoosier Association of Science Teachers, Incorporated. He has been president-elect, president, and past president of AETS.

Indiana University recognized his excellence in teaching with a distinguished teaching award in 1972. A survey of the Indiana University Class of 1970 showed Dr. Andersen to be among the top ten I.U. professors named as a person who positively influenced their lives. He has authored numerous articles and textbooks concerning science education curriculum and instruction.

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Dr. Beisenherz has authored articles in professional journals and has presented workshops and papers at regional, state, and national meetings. He was a contributing author of chapter, "Improving Middle School Science Instructional Practices through In-Service: In-Servicing Metropolitan Districts" in the 1981 AETS Yearbook.

Dr. Beinsenherz was the recipient of the AMOCO Outstanding Teaching Award within the Louisiana State University System in 1979. He has conducted numerous pre-service and in-service workshops for science teachers, including an NSF-Sponsored CCSS project for elementary teachers.

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From 1966 until 1971, he was staff physicist for the Science Curriculum Improvement Study. During that time he was on the editorial board of the Physics Teacher. In 1971, he went to work as Director of Science Education for the Detroit Edison Co. In 1972, he became Associate Professor of Science Education at the University of Michigan and in 1977 was nominated Professor of Science Education.

He holds his Bachelors Degree from the University of Denver, Masters from California State University at Sacramento, and his Doctorate from the University of California at Berkeley. He was written numerous articles and books; his most recent book series being Science, published by the Houghton Mifflin Publishing Company.

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J. DUDLEY HERRON completed the A.B. in education at the University of Kentucky in 1958. He was a chemistry teacher and science supervisor for three years in Woodford County (Kentucky) Schools, interrupting his tenure there to complete his M.S. degree at the University of North Carolina in 1960. He taught high school chemistry and physical science in the Army dependent school in Kaiserslautern, Germany, for one year before continuing graduate study at The Florida State University. After completing the Ph.D. in Science Education at Florida State in 1965, he came to Purdue University where he has held a joint appointment in chemistry and education since that time. In the fall of 1968 Professor Herron was on leave at the American Association for the Advancement of Science to coordinate the teacher education project that resulted in guidelines for the pre-service science education of elementary school teachers. In 1972-73, he was on leave to the Regional Education Centre for Science and Mathematics, Panang, Malaysia, where he served as training adviser. Dr. Herron's research interests are in application of Piaget's theory of intellectual development to the teaching of chemistry. He recently published a textbook for a college preparatory chemistry course which grew out of that research.

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Dr. Koran taught biology in Banning, California, and was an administrator at the seventh grade level in Palo Alto, California. He has published a number of technical reports, pamphlets, research studies, and theoretical articles in science education and has presented papers both nationally and internationally.

In 1973, Dr. Koran was named the Outstanding Science Educator, an award presented jointly by the AETS and the Shell Oil Company. In 1976 he received the Annual Research Award of the Association of Teacher Educators (ATE) and the Patron's award of the National Association for Research in Science Teaching (NARST). He has also served two terms on the Editorial Board of the Journal of Research in Science Teaching.

CHERYL MASON attended Indiana University, where she received a Bachelor of Arts degree in Biology in 1970; a teaching certificate in 1971; and a Master of Arts degree in 1975.

Her teaching career began with the School Town of Highland in 1971. Subjects that she taught include 7th, 8th, and 9th grade general science; and basic, general, and advanced biology. The format for her classroom instruction is individualization based on mastery level objectives.

Two years ago, Mrs. Mason instituted a science honors seminar. This course is designed for high school students interested in doing research and other in-depth studies beyond those available in the normal classroom. In addition, she teaches a biology course at Purdue University-Calumet.

Extracurricular activities include sponsoring a model rocketry club for two years and a science club for the past six years. The science club has achieved local, state, national, and international recognition for various student research projects and other areas of science competitions. Mrs. Mason has been highly involved in student science organizations throughout the state, serving as a council member for both the Indiana Junior Academy of Science and Indiana Science and Humanities Symposium. Also, she is a member of the Youth Activities for Indiana.

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Over his six-year career at SIU-C, Dr. Rubba has been active in research, publications, and service. His major areas of research interest are citizen scientific literacy and student/teacher understanding of the nature of science. He has authored or co-authored research reports and articles in these areas of research and in others, which have appeared in The American Biology Teacher, the Journal of Research in Science Teaching, the Journal of Science and Mathematics Education in Southeast Asia, School Science and Mathematics, Science Education, and The Science Teacher, among other professional journals and publications.

During 1980 and 1981 Dr. Rubba received three science teacher training grants from the National Science Foundation, including one to offer developmental reasoning workshops to Illinois junior college, college, and university science instructors. He has been a frequent presenter at NSTA conventions and at science teacher meetings in Illinois. Between 1978 and 1980, he served as southern region coordinator for the Illinois Junior Academy of Science. He is presently a member of the Illinois Science Teachers Association Board of Directors. In 1979, Dr. Rubba was named an Outstanding Young Man of America under a program endorsed by the U.S. Jaycees.

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His professional interests have centered on educational change and innovation, the artistic aspects of teaching, and staff development. A widely known speaker, he has lectured in Europe, Africa, Asia, and South America, as well as throughout the United States.

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Mrs. Schultz graduated from Simmons College, Boston, with a B.S. in chemistry and received her master's degree from Northeastern University, at Boston University and Brown University, and completed two years of training at the Eastern Institute for Group and Family Therapy to achieve a better understanding of interpersonal relationships. Following graduation from college, she worked as a research associate in the Department of Physical Chemistry, Harvard Medical School, Boston. She entered the field of science education after a short leave to begin raising a family.

Believing that constant involvement in professional activities leads to a revitalization and renewal of a teacher's energy, enthusiasm, and effectiveness, Mrs. Schultz has been very active in professional organizations. She is a member of AAAS, ACS, NEACT, NSTA, NEA, and their state and local affiliates. A very active member of ACS, Mrs. Schultz has served as chairman of the Lyman Newell Award Committee for the Northeast Section, is currently serving as the elected Member-At-Large of the Executive Board of the Division of Chemical Education of ACS, is High School Chairman of the 1984 Biennial Conference of DivChed to be held at University of Connecticut, and has been a member of the High School Chemistry Committee of DivChed since its inception in 1979. She is currently serving her third term as Central Division Chairperson of the New England Association of Chemistry Teachers, has served on the Awards and Recognition Committee of NSTA, and is active in her own school and community in both school and non-school related activities.

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Ila has college credit from Butler University, and Purdue University, an A.B. degree from University of Michigan and a Master's Degree from Indiana University in elementary education with emphasis on science. She taught science at the sixth grade level in the Mitchell Schools for seventeen years. After retiring in 1980, she has written some articles for the Hoosier Science Teacher and one item for Science and Children, and has served on a North Central Evaluation Committee for a middle school. She still finds time to help her teacning husband by acting as laboratory assistant on busy days.

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Summers were devoted to continued academic work, and Mr. Staver was awarded the degree of Master of Science from Purdue University in 1973. He again majored in chemistry. In 1975 he returned to Indiana University to do full-time doctoral studies. He majored in science education and was awarded the degree of Doctor of Education in 1978.

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PART I

# A TYLERIAN APPROACH TO SCIENCE CURRICULA

Louis Rubin
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Perhaps the most notable thing about Ralph Tyler's celebrated rationale for curriculum development is its longevity. Conceived in 1949, it has since been the subject of endless debate and discussion. More than anything else, perhaps, the model's continuing popularity is tribute to its universal applicability. Essentially a process for identifying instructional objectives, the model has as much utility today as it did 30 years ago. Its timelessness, of course, stems from the fact that it provides not solutions, but procedures for finding solutions. As a result, it has as much utility in art and history as in science, and, presumably, will be as useful in the year 2000 as it is now.

Reduced to its simplest dimensions, Tyler's rationale is essentially a scheme for analyzing and integrating the various elements which play a part in curricular decision-making. The scheme can be conceived of as a four-phase methodology, involving seven specific steps. In the first phase, the three traditional footings of curriculum are examined in order to select a primary set of instructional objectives. Thus, step 1 involves an examination of student interests and characteristics; step 2 consists of analyzing societal problems and trends; and in step 3, the standard disciplines are synthesized so as to identify the information of greatest utility. Next, in Phase Two, the fourth step involves conjoining the objectives chosen in steps 1-3 into a cohesive program of aims. Phase Three, finally, is given over to a secondary reconsideration of these aims. Each objective is re-evaluated to ensure that it is congruent with the established educational ideology and accepted principles of learning. Hence, in step 5, the curriculum designer's particular conception of instructional purpose serves as a kind of filter for refining the selected objectives. In step 6, the objectives are again scrutinized and appraised, this time in the context of current learning theories. Lastly, in the seventh step, the goals which have been processed in the previous operations are arranged in an organized pattern. Ultimately, these are fitted into specific learning experiences which can be evaluated.

The model, obviously, will yield varying curricular objectives with different theorists -- and at different points in time. Professionals often disagree in their appraisals of student and societal needs, in their individual conceptions of educational purpose. Similarly, during periods of conservatism the curriculum will tend to be somewhat more constrained than at other times. This inconstancy can be construed as both an advantage and a disadvantage. On the plus side, the flexibility allows educators to construct a curriculum appropriate to the prevailing conditions. Thus, when social values appear to be somewhat unbalanced, schooling can be realigned in order to reinforce the democratic ethos. On the minus side, however, there is an abiding danger that instruction will waffle unduly between opposing philosophies, suffer from internal inconsistency, or skew excessively in one direction or another. Vacillation of this sort is also likely to be perpetuated by changing aspirations among youth, cultural shifts, and new research evidence on teaching and learning.

For Tyler, there are both educational and social dimensions to choosing instructional aims. He wrote:

> An educational program is not effective if so much is attempted that little is accomplished. It is essential therefore to select the number of objectives that can actually be attained in significant degree in the time available, and that these be really important ones. Furthermore, this group of objectives should be highly consistent so that the student is not torn by contradictory patterns of human behavior. Values suggest educational objectives in the sense that they suggest the kinds of behavior patterns; that is, the type of values and ideals, the habits and practices which will be included and suggested objectives which are inconsistent with these values will not be included in the school's educational program. (1949, p. 34-35).

To use the model as Tyler intended, schools must ponder and resolve a number of basic issues. Should, for example, the instructional program emphasize material and financial success? Should public education vary in order to accommodate different groups within the society or adhere to the universal program of greatest utility? And, as the author himself asked: "Should the school develop young people to fit into the present society as it is, or does the school have a revolutionary mission to develop young people who will seek to improve the society?" (1949, p. 35) It is worth noting, perhaps, that we are no closer to a permanent resolution of these disputes today than we were in 1950. As a consequence, it probably is fair to say that the rationale will always be subject to deviations in human opinion.

Tyler was convinced 30 years ago, as indeed he is today, that every curriculum-maker must make use of some theory of learning; that is, some conviction as to how student achievement can best be encouraged. Such a "psychology of learning" must emanate from the accumulated studies on learning processes, as well as from the specific principles of knowledge acquisition and skill development. Moreover, to be usable, the operational elements of a psychology of learning must be formulated in concrete terms so as to provide a screen for judging the utility and feasibility of alternative objectives. In this way, ~~a faulty~~ instructional aim can be rejected, as Tyler said, "because it is probably unattainable, inappropriate to the age level, too general or too specific, or otherwise in conflict with the psychology of learning." (1949, p. 43) Here again, new insight from experimental research is likely to alter the shape of curricula. Currently, for example, the postulations of Carrol and Bloom, the data assembled by Medley and Gagne, the conceptions of Cronbach, and the postulates of Bandura, could all be meshed with the earlier research of Thorndike and Judd in devising a selection screen.

By way of recapitulation, then, it would seem reasonable to suggest that the model's great strengths lay in its flexibility, its systematic provision for processing the major variables in the curriculum formula, and in its mechanisms for repeated reassessments. But on the other side of the coin, it makes no precise recommendations regarding content; it is vulnerable to judgmental error, particularly with respect to individual biases regarding student and societal needs; it is subject to inferential error at each of its seven steps; and it is -- in itself -- independent of political consideration. At any particular point in time, for instance, the model may point in directions which run counter to the prevailing mystique. Presently, as a case in point, it might be necessary to by-pass humanistic objectives in favor of aims which jibe more closely with the conservative tenor of the movement.

It is interesting to note that almost two decades after it was conceived, Tyler used his own rationale in appraising the status of science education. His 1967-1968 diagnosis of the ills besetting the field focuses on the conspicuous shortage of adequate theory, and the need for further experimentation in order that teaching be grounded more fully in systematic procedures. Subsequently, he outlined a program of research aimed at developing "an adequate map of the factors and processes in science education." (1967-68, p. 43). His recommendations illustrated the then mainstream belief that the curriculum ought to reflect on the major concepts incorporated in a discipline and that teaching should increase the student's problem-solving capability. This view was further expanded in a publication of the National Academy of Education (of which Tyler was first president) that was edited by Lee Cronbach and Patrick Suppes (1969), and again echoed in Paul Hurd's 1970 NARST presidential address.

Only a few years later, however, Glass took a position diametrically opposed to Tyler's. His essay contended that:

> . . . we should not strive to make research on science education or education generally more scientific. Indeed, we who call ourselves educational researchers should turn away from elucidatory inquiry in all areas of education. This type of inquiry, directed toward the construction of theories or models for the understanding and explanation of phenomena, should be left to the social and natural sciences because it is currently unproductive in education and is a profligate expenditure of precious resources of time, money, and talent. (Glass, 1972, p. 3)

Periodically, during the recent past, the rationale has again been taken to task by one critic or another. For example, Joseph Schwab has contended that our traditional approaches to curriculum design are inadequate, and the "theorizing" may not constitute the best way to reach the right conclusions. Even in the instances where theorizing is appropriate, he maintains, the resulting theory often is of the wrong sort. Other commentators are bothered by the fact that an inept theorist could easilty produce a mediocre curriculum with Tyler's model. Whether or not such criticism is justified remains a moot point. One would think, however, that since most tools are no better than their users, clumsy utilization should not be interpreted as a failing of the process itself. The more important consideration, seemingly, is that a skillful curriculum specialist could -- through the Tyler methodology -- create an effective instructional program.

It is also possible that Tyler's theories of instructional organization could be useful in rebuilding science curricula. His organizational recommendations centered on the principles of continuity, sequence, and integration. Continuity stemmed from his conviction that significant ideas must receive recurring emphasis; by sequence he intended that -- in this recurring emphasis -- the ideas be treated in progressively greater depth and scope; and integration was meant to suggest that ideas learned in one area of the curriculum ought to be related to other learning. If, as an illustration, the student acquires a beginning understanding of percentage in arithmetic, percentage can also be reinforced during the study of, say, nutrition.

In advocating such a scheme, he made it plain that it was of considerable importance to distinguish between the integration of subject matter from the reference point of an expert and a student. That is, interrelationships apparent to an expert may not be comprehensible to a student encountering the ideas for the first time. Hence, it is necessary to exercise judgment in the linking of instructional content, and to ensure that the relationships stressed are appropriate to the student's level of psychological development.

Tyler also conjectured that concepts (humans influence their physical environment), skills (extracting relevant information, and values (social justice) could all be used as additional organizing elements. The intellectual substance of any discipline, in other words, can be distilled into discrete bodies of major concepts, essential skills, and desirable values. Lastly, as yet another organizing mechanism, he suggested that knowledge could be arranged (a) according to specific subjects (biology), (b) in broad fields (physical science), and (c) core curricula (content contributing to general education).

An up-dated utilization of Tyler's notions could be achieved in a number of ways. A current topic, perhaps energy, for example, could be organized in a manner wherein concepts, skills, and values serve as connective tissue. Similarly, the elements of continuity, sequence, and integration could easily be used in planning instruction on science-related social problems.. Dilemmas associated with food production, as an illustration, might be taught sequentially, and in gradually increasing complexity, during the K-12 program. Or, to increase learner sophistication regarding next-generation technology, such matters as electronically transmitted -- as opposed to paper communicated -- messages, DNA, integrated chip-circuitry, and photovoltaic cells might be explored. Similarly, by way of perpetuating instructional unity, the effects of robot-intensive manufacturing on unemployment could be considered in various subject contexts. Or, learning units might be devised around the probable nature of a computerized society (current projections are that roughly 43 million households will own home computers by the mid-1980's). In turn, each of these issues could be incorporated into a general theme dealing with the societal future. Learner insight might thus be cumulatively developed with regard to human interdependence, the management of scarce natural resources, environmental conservation, and so on.

At the risk of seeming self-serving, I am tempted, at this point, to interject a personal bias of my own. Tyler entitled his monograph <u>Basic Principles of Curriculum and Instruction</u>. Moreover, in connection with instruction he observes, on page 64, that the learner's reactions to the classroom experience determine, in large measure, what is learned. "The teacher's method of controlling the learning experience is through the manipulation of the environment in such a way as to set up stimulating situations -- situations that will evoke the kind of behavior desired." (1949, p. 64) Such "manipulation" jibes closely with my own convictions regarding artistry in teaching.

An old aphorism holds that success and failure are both addictive. Nowhere, perhaps, is this more true than in teaching and learning. The child who, under the ministrations of an expert teacher, learns effectively develops a sense of adequacy and a taste for attainment. Conversely, the student who falters because of inexpert guidance grows accustomed to floundering. Recognizing this, gifted teachers seek to turn the psychological tides in their own favor.

To attempt a definition of artistry is, in a sense, to seek the impossible. Because it is by nature amorphous, occurring in an infinite variety of forms, the analysis of artistry is, if anything, more difficult than its definition. Yet without attempting to understand its infrastructure we cannot perpetuate its development.

The characteristics associated with artistry come readily to mind: skill, originality, flair, dexterity, ingenuity, virtuosity--and similar qualities that, together, produce exceptional performance. One might also argue that artistry consists of master craftsmanship through which tasks are conceived, planned, and executed with unusual imagination and brilliance. Or, to approach the phenomenon from still another perspective, one could say that artistry stems from the subtle discrimination and judgment that are the by-product of extraordinary perception and taste. Regardless of the descriptive terms which are used, however, artistry implies human performance that is unusual in its proficiency and cunning, and greatly superior to conventional practice.

Applied to teaching, artistry involves (a) the choice of aims that have the highest worth, (b) the use of imaginative and ingenious ways to achieve these aims, and (c) the accomplishment of the aims with great skill and dexterity. From even this elementary analysis it is plain that artistry involves attitudes and intentions, knowledge, discernment and astuteness, and uncommon competence. These, moreover, must be blended together into an integral force. Great skill wasted on trivial objectives, virtuous intentions pursued unimaginatively or without ingenuity, and well-conceived tactics that are executed poorly all defeat artistry. The cultivation of high performance, consequently, requires that teachers adopt a shrewd conception of educational purpose, exploit their capacity for creative invention in accomplishing these purposes, and continually enlarge their repertire of technical skills.

These three efforts, moreover, must be conjoined in a nexus -- a framework -- that accommodates the classroom setting, the temper of the students, and the requirement of reality. It would be senseless, for example, to choose objectives which run counter to public expectation and acceptable educational ideology, or to devise teaching gambits which are unsuited to the learners, or to develop a technical repertory of instructional strategies which are incompatible with the school organization. Function, in short, is everything.

Artistry converges around the teacher's dexterity in organizing and directing learning exercises. The genesis of this form of deftness stems from imagination, creativity, desire, and a consummate understanding of both subject and learner. Certain people are admired for their ability to entertain guests. Their skills stem not merely from the "logic" that enables them to choose a tasteful menu, but also from an intuitive sense about a good "mix" of people, an ability to create an appropriate ambience, and a flair for initiating conversation that people find provocative. Some clergymen, through an extra gift, seem to go beyond the routine demands of the ministry and establish among their parishioners feelings of camaraderie, belongingness, and identity. Their success in this regard derives not from brilliant sermons nor compassionate pastoral counseling, but rather from adeptness in promoting an infectious group spirit. Similarly, many teachers -- who are neither extraordinary scholars nor blessed with spectacular interpersonal skills -- nonetheless create exciting classrooms. The things that go on in these classrooms are, for the children involved, fun. Although solid learning occurs, the events sometimes seem more like play than work. There is, after all, nothing cheap about baiting learner interest; only cheap bait is cheap. The classroom drama is "staged" with sensitivity, high style, and finesse. The teachers who plot the flow of such learning recognize that intellectual play is at times as instructive, and infinitely more pleasant, than intellectual drudgery.

Those who eventually attain the highest level of artistry are distinguished by four primary attributes: first, they make a great many teaching decisions on the basis of intuition; second, they have a sound knowledge of their subject as well as a perceptive understanding of their students; third, they are compassionate and "helpful" individuals; and fourth, they are imaginative.

The virtues of common sense, intuition, and imagination appear to have become a lost cause in teacher training. The loss is perhaps understandable in view of our strenuous efforts to organize better instructional systems, but it is nonetheless regrettable. Inspired teaching will never be encapsulated in a system. This is not to say, obviously, that research on teaching should cease or that teachers, in their training, should no longer be familiarized with techniques that have been found effective. There are, however, subtleties and nuances in teaching that cannot be prescribed in advance. A major dimension of artistry, in fact, involves the ability to take adroit advantage of unanticipated opportunities -- in short, to capitalize upon the "ripeness" of the moment.

What then are the implications of the model for science education? Underlying the specific problems described elsewhere in the volume are a number of general issues. In the chapter which follows, for example, Professor Yager outlines a number of egregious dilemmas which continue to bedevil the craft. He notes, as a case in point, the continuing dichotomy between instruction emphasizing basic science literacy and instruction geared toward promoting allied careers. And, as another illustration, the lack of consensus regarding the desirable redirection in curricular thrust -- if allowed to go unremedied -- can only lead to confusion, uncertainty, and inconsistency.

That a transition of some sort is essential seems indisputable. As Yager suggests, societal conditions are in transition, the technology of teaching and learning has altered, student interest in science has declined, and the schools of the 80's appear to have somewhat different concerns than those of the 60's and 70's. It therefore is important to clarify any misconceptions which exist, as well as to redefine the dominant objectives in science education. Since most of the other chapters in the volume deal, in the main, with science teaching proper, it perhaps would be sensible, in this segment; to explore implications resulting from Tyler's suggested analysis of general social trends.

If we heed his admonition that it is necessary to determine what educational purposes are most worthy, and then decide which experiences best accomplish these purposes, we must, as he advises, begin by examining contemporary life as one source of evidence. When we do so, it immediately becomes apparent that the times are characterized by extraordinary disjunction. Not only is the social system in flux, but major elements in the cultural matrix are shifting -- sometimes in conflicting directions -- because of various contradictory pressures. We are entering a new economic era, one that is likely to modify our patterns of work and leisure. The mounting onslaught of technology will necessitate an adaptation to different ways of doing customary things. And, as the psychic excesses of the last few years continue to haunt us, we may be compelled to again accept the ethics and values which were abandoned in the existentialism of the past two decades. Each of these, self-evidently, affects comtemporary life and thus -- in the spirit of the Tyler rationale -- mandates corresponding adjustments in the curriculum.

Tyler himself anticipated that basing curricular decisions on the conditions represented in contemporary life posed certain risks. Nonetheless, he suggested that a study of existing culture is critical for two reasons: first, since the social scene is complex and in constant undulation, it is important to focus some instructional objectives on the societal conditions with which students will need to cope as adults. Second, because he was skeptical about some of the assumptions underlying faculty psychology, Tyler doubted that "transfer of training" is an automatic outcome of instruction. Moreover, he questioned whether the teaching of a few intellectual skills would enable the student to use acquired knowledge in the right way and at the right time. Accordingly, he reasoned that students are much more likely to apply their learnings when they recognize the similarity between situations encountered in life and those they studied in school. Furthermore, he believed that the student is more likely to perceive the similarity between the life situations and the learning situations when two conditions are met: (1) when the life situations and the learning situations are clearly alike in many respects, and (2) when the student is given practice in finding illustrations, in his life outside of school, of ideas learned in the classroom.

Yet, despite these persuasions, he was not insensitive to the objections raised by other theorists. Some critics, for example, argued that the curriculum should discriminate between ongoing events -- and their desirability. To wit, the fact that many people currently are dedicated to greater self-fulfillment does not necessarily mean that a preoccupation with self-fulfillment is healthy. Objections also were raised because of the temporal nature of life styles. Since living patterns constantly change, reviewers suggested, it would be unwise to organize education around customs which might -- or might not -- exist during the student's adulthood. Still other detractors, concerned about the relevance of the curriculum, were quick to point out that students often had little interest in the affairs of adults and would therefore find such subject-matter immaterial.

Tyler's response, to all of these objections, was that an analysis of contemporary life constituted but one source of instructional goals. In the final determination, when the data obtained from other sources were taken into consideration, a balanced course of study would be achieved, and the dangers alluded to by the critics would be offset.

Assuming, then, that various data are used to equalize the formula for science education in the period ahead, what can be deduced from the current scene? Even the most optimistic of social observers now concede that our present decade will be a difficult one. We must be content with an economic shortfall that will demand major readjustments in the abundance-oriented modes of the past. It will be a bit more difficult to find jobs, purchase homes, pay for luxury foods, and so on. Moreover, because the gulf separating the rich and the poor tends to widen during times of scarcity, we can expect more and more conflict over the ways in which our dwindling resources are divided.

In addition, some signs of social disorientation are beginning to appear. Twenty years ago, it must be remembered, we engaged in a remarkedly abrupt departure from traditional convention. As the alienation from long-standing values deepened, divorce became more prevalent; home, family, church, and work lost their centrality; the recreational consumption of drugs increased; mores regarding sexual conduct liberalized; and -- prompted by repeated urgings in the popular media -- a cult of self-absorption began to develop. Now, confronted with the economic realities and faced with the realization that the counter-culture movement may have led us a bit astray, we are beginning to have second thoughts.

Whether the tides are irreversible remains to be seen. Irrespective of the periodic undulations between social conservatism and social liberalism, however, it seems certain that the future will be like neither the present nor the past. The rise of the Moral Majority was as attributable to the nagging fear that our values were in disorder, as to political doctrine.

There are other indicators, as well, of the cultural revolution in process. Attitudes toward work, for example, are vastly different from what they once were. Not only are a majority of women now employed outside the home, but family dependence upon a double income has become commonplace. As a consequence, the problems of adequate child care have become exceedingly serious. And as a consequence of more employed women, and a gradual redefinition of sex roles, many males, no longer driven by their old responsibilities as heads of households, are opting for shorter hours, earlier retirement, and frequent job shifts.

Not surprisingly, among the young, conceptions of the good life alos have changed. Earlier generations were impelled by a strong desire for stability, ready money in the bank, and vocational prestige. The present cohort, in contrast, is more "laid back," more concerned about the purposes of their labor, and more interested in work which is personally rewarding. There is, in the same vein, less deference to authority, less subservience to management, and less concern for high productivity.

The ancient dictum regarding moderation in all things, too, has suffered a turnabout. There was a time when people believed that happiness was to be found in wanting what one had, rather than in having what one wanted. For many, it is no longer so. The material temptations of affluence aside, we simply came to expect infinitely greater self-gratification during the halcyon days of our hedonistic splurge. Currently, having both discovered the impossibility of endless pleasure -- and rediscovered the importance of balance -- a period of reconciliation is underway. To be sure, the ideas of expanded experience, personal gratification, and life quality were not without their benefits: we learned that something more was possible. What now remains is to reestablish equilibrium.

Some of the readjustment, perhaps, must center on commitment to the societal welfare. It is, of course, entirely human to oppose governmental error and to be heavily involved in one's own well-being. Yet, in the aftermath of the protest marches, draft-card burnings, and sit-ins, we may have lost some of the pride and dedication that are essential to national health. As the nation responds to its present crises and begins to find its way in the changing world, our customary commitment and sense of social obligation will, in all likelihood, return.

Finally, to note another of the multiple indicators of societal upheaval, the structure of the family unit has altered sharply. Once again, the dramatic reversals of the past reflect new conceptions about how life can, and should be, lived. Interest in marriage has declined from a point in days gone by -- when virtually everyone anticipated wedlock -- to the present circumstance where large numbers of youth prefer other alternatives. More, even among those who do marry, parenthood no longer is an expected concomitant. In short, millions of youth seriously question the merits of having children. One reason, possibly, is that the "til death do us part" notion has largely eroded. In sharp contrast to their parents, today's young do not uniformly regard marriage as a permanent state. Divorce, resultingly, has become not only socially acceptable but commonplace. Many of those who choose not to marry take refuge in "live-ins." Once regarded as a disgrace, cohabiting with someone -- of either sex -- to whom one is not married is now seen as a customary option. Because of these deviations in the traditional structure, the number of single-parent families has risen 70 percent in the past 20 years. Given these trends, what can be said about the future of science education? The implications which can be drawn, obviously, have a bearing on the entire curriculum, but they nonetheless apply to science as well.

Perhaps the first point to be made is that because widespread publicity has centered upon the alleged decline in scientific knowledge, and in reduced student interest in studying science, efforts should be made to correct any deficiencies which exist. Admittedly, good science education must go beyond a knowledge of mere facts and laws, but so long as student achievement and involvement are below par, criticism is likely to continue. For similar reasons, anything which can be done to provoke greater student interest in science-related careers will be beneficial. It is possible, in this regard, that the press for "basics" may, in the last analysis, hamper a general revitalization of the science curriculum but, alas, first things still must be put first.

A second point concerns the impact of societal shifts. The trends provide evidence on two of the components in Tyler's formula: "contemporary life" and "the learners themselves." It is doubtful whether science education can -- or for that matter, should -- attempt to modify the value changes underscoring the transformations taking place. It can, however, anticipate the consequences of the movements and seek to forearm youth. Much might be gained, for example, if students were to grasp a sufficient amount of scientific lore to understand and utilize the technological advances, now on the frontier, that will profoundly affect the way we live.

For a third point, logic would suggest that since most of the critical problems people will face in the time to come have scientific dimensions, students must have a solid foundation in the science-related principles and concepts. At a recent convocation (Exeter, 1980) of science educators, for example, it was suggested that present science courses often give insufficient emphasis to such topics as genetic engineering, pollution, and conservation. It might also be said, in this regard, that the learning of chemistry, physics, and biology are of little avail if they do not equip the learner to understand the scientific underpinnings of population control, energy, food production, and so on.

Reference is frequently made, these days, particularly in connection with test scores, to the failings of science curricula. Such indictments may, or may not, be valid. It seems reasonable to conjecture, nevertheless, that if failings do exist, they are as much a result of the continuing cultural revolution as anything else. Thus, the special virtue of Ralph Tyler's curriculum thesis is made apparent: as times change, and as people adopt new life patterns, the curriculum grows obsolete. It then becomes necessary to re-think the dominant instructional responsibilities of the school. Science education, perhaps is presently at this point.

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# THE CURRENT SITUATION IN SCIENCE EDUCATION

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## HISTORICAL PERSPECTIVES

More than three decades have passed since Tyler (1949) proposed his model for curriculum development and instruction. These 32 years provide many opportunities for assessing the current situation using Tyler's model. The period has been one of rapid change in terms of societal imperatives/ demands for science education, in terms of the nature/number of secondary school students enrolled in science, and in the definition/organization of the content of science.

The decade prior to 1950 was one in which the science offered in secondary schools could be characterized as one with an emphasis upon applications of science. These were the "war years" when it was commonplace to emphasize technology often related to such fields as communication, transportation, and industry. Many saw too much emphasis upon the applications of science and too little input from the scientific community. Some saw a natural progression based on the progressive ideas advanced by John Dewey from an earlier time. After all, it was Dewey who eloquently called for learning that could affect daily living--learning by doing.

The years following World War II produced many who condemned the mainline science of the time. These attacks were often led by the scientific community which was concerned with the absence of science considered in research laboratories, the science needed for major breakthroughs in the various disciplines of science, and the science needed as preparation for collegiate studies in scientific fields. This movement was exemplified by the formation of the Physcial Sciences Study Committee in 1956. This committee formulated specific plans for a new kind of physical science for the secondary school curriculum.

And then the Soviets launched a man-made satellite into orbit around the earth in 1957! This launching of Sputnik produced massive public support for changing (improving) science education in the United States. Sputnik triggered much pressure for a new science education as a way of "catching up with the Soviets."

Funding for science education in the National Science Foundation was increased dramatically. Science education activities were supported as a part of the original mandate when the Foundation was created in 1950, one year after Tyler advanced his curriculum and instruction model. The demands of society, the needs of students, and new concepts of science disciplines all combined to produce new general objectives and a so-called new school science following Sputnik.

The Physical Science Study Committee which had been formed prior to Sputnik was suddenly funded to produce a new physics course. This effort was the first of many national science curriculum efforts which continued through the decade of the 60's and into the 1970's. During this period of nearly 20 years, more than $100-million were directed toward course content improvement efforts for school science. Increased support for science education came from the U.S. Office of Education, state departments of education, private and public foundations, increased support by local school boards (often on the basis of matching funds), and direct support for re-training in-service teachers. Approximately $2-billion were funneled into improving science education during the two decades following the launching of Sputnik.

To be sure, many different science programs were developed during the 1957-75 period. Also, there were significant differences between the science materials supported and produced in the early 1960's and those of the early 1970's. It is easier to characterize the earlier efforts because there was more universal agreement concerning the general objectives for science teaching as defined by society, student needs, and the subject matter of science. The early 1970's were transition years, and the interest of the public and the public financial support for improvement efforts were much more limited.

The 1960's have been fondly called the Golden Years for science education. Science courses, science teachers, and efforts to improve both were supported by the general public--often without question. The curriculum (or course improvement) efforts were headed by the scientific community with some support from the philosophical, psychological, and classroom teacher communities. Teacher training activities for which significant financing was provided for institutes and a variety of special programs were also in the hands of the scientific community. The efforts were clearly to develop science courses which reflected the newest developments within the various science disciplines and to help teachers improve their subject matter competency for teaching them.

These so-called Golden Years were shaped by two central ideas. One came from the scientific community--the architects of the PSSC physics course. It was purported that science would be inherently interesting to all students if it were presented in a way that is known to scientists. The other idea came from the psychological community and was central to the Woods Hole Conference report which preceded the national curriculum efforts. Bruner (1966) proclaimed that any subject could be taught effectively in some intellectually honest form to any child at any stage of development. These two ideas served as the philosophical and psychological screens from Tyler's model that affected the instructional objectives and the selection and organization of learning experiences for students.

Formulating instructional objectives was not a major activity for curriculum developers during the 60's. Many developers during that time reported that instructional objectives were foreign to practicing scientists. One of the early curriculum directors is reported to have responded when asked about the instructional objectives for one of the new courses: "Objectives? Objectives? Why do you need to ask? You should be able to see the course objectives by looking at the textbook!" For some curriculum developers instructional objectives were formulated after the development of course materials, pilot programs, and first publication of the new course. Some now see this as a major flaw in the efforts of two decades ago. Was enough time spent in debating and formulating specific instructional objectives?

In retrospect, Tyler's model seems appropriate to explain the science education efforts of the 60's. Society was demanding an "improved" science education to soothe a wounded national pride that resulted from the impressive Soviet move into outer space. The American public was demanding a more rigorous science--a science that would produce more scientists and engineers to meet a perceived societal need. The scientific community provided needed direction in determining course content that was closer to the science occurring in research laboratories. Students were caught up in this national effort for improvement; they enjoyed the extra attention and the recognition provided by new curriculum materials, enthusiastic teachers fresh from institute experiences, and the interest of family and community members.

The decade of the 70's was different. The public became disillusioned with science, interest in school science declined, support for more curriculum development and teacher re-training decreased significantly. There were new societal demands and pressures. The Viet Nam War resulted in conflicts, disillusionment, and re-evaluation of priorities. Some blamed the conflict upon science and technology. Some saw other major societal demands as caused by over-emphasis of and over-dependence upon science. These problems included environmental degradation, energy depletion, failure to conquer cancer and other human diseases, population explosion, and worldwide starvation. Perhaps society expected too much of science; perhaps too much was promised or assumed; perhaps the unquestioned support for science a decade earlier was wrong. To be sure, the stormy 1970's were not the same as the confident, purposeful, and supportive times of the 1960's.

The 1970's brought attacks on curriculum development supported by public funds. Major forces attacked the new materials as "un-American," inappropriate, even pornographic. Debates concerning these efforts were conducted in the Congress of the United States. After much discussion, national and public review, delays, and some considerable financial cut-backs, most of the curriculum efforts begun in the 1970's were completed in one form or another. However, not all received national exposure, resulted in published versions by mainline book publishers, or enjoyed support for teacher in-service activities.

The 1970's also witnessed attacks by textbook publishers on policies that called for support for in-service teacher activities that complemented the new curriculum efforts. Publishers of materials not developed with federal funds objected that teacher support for programs designed to help schools/teachers implement the new programs was actually unfair business practice. The scientific community also objected to programs for teacher in-service that merely assisted with implementing new programs instead of providing for more in-depth training in subject matter <u>per se</u>.

This national debate became so great that federal support for curriculum development all but terminated in 1976, and all funds to support pre-college teacher education activities were diverted to other science education efforts. Therefore, 1976 became a pivotal year in the assessment of the current situation in science education. It was a peculiar time in terms of societal demands and expectations for science education. It was an uncertain time in terms of students needs for a science education. It was a curious time, as major advances in science continued while dominance of the scientific community in school science efforts was questioned. It was a time when new general objectives (as per Tyler's model) were being formulated.

In this setting, the National Science Foundation, in response to Congressional pressure, awarded three contracts in 1976 to assemble information to provide a picture of K-12 science education. An attempt was to be made to assess the impact of public support for science education during the preceding 20 years. Were the improved courses and the support for teacher education successful? Had science education kept pace with science, society, knowledge, and schooling?

Each of the three studies was designed from a different perspective. Helgeson (1977) and his colleagues at The Ohio State University summarized the published and unpublished literature concerned with science education during the 1955-75 period. The information surveyed centered upon practices in schools, instructional materials, teacher education, administrative/financial control, and needs in K-12 science. A second study, headed by Iris Weiss (1978) of the Research Triangle Institute, was a national survey of teachers, administrators, supervisors, and other school personnel. Questionnaires were used to obtain information concerning curricula, course offerings, teaching methods, enrollments, individualized materials, teaching assignments, support services, and demographic information about teaching practices. The third study, conducted by Stake and Easley (1978) of the University of Illinois, consisted of 11 case studies and an in-depth analysis of the reports prepared by extended on-site visits to the schools. Each selected school represented a different type of community. The three NSF status studies, then, were designed to survey what the literature revealed about the state of K-12 science education, what professionals reported to be happening, and what professional observers saw in a sampling of schools.

While the NSF studies were underway, the third assessment of science as a part of the National Assessment of Education Progress (NAEP) was conducted (1978). It, too, provided information about the results of instruction in science across the United States. The third NAEO assessment included a new battery of items that provide information about the affective outcomes of science education for nine-, thirteen-, and seventeen-year-olds, as well as for an adult sample. Norris Harms, then at National Assessment headquarters, was the architect of this information that supplements the achievement data which provided the major focus of the two earlier NAEP assessments.

Prior to the final printing and distribution of the three K-12 status studies, the National Science Foundation awarded nine contracts to nine professional groups to read the three studies in their existing formats and to report on the meaning of the studies for their respective memberships and for the science education community. These groups included:

1. American Association for the Advancement of Science;
2. American Association of School Administrators;
3. Association for Supervision and Curriculum Development;
4. National Academy of Sciences, National Research Council;
5. National Congress of Parents and Teachers;

6. National Council for the Social Studies;
7. National Council of Teachers of Mathematics;
8. National School Boards Association; and
9. National Science Teachers Association.

This set of reviews is extremely interesting to read and to analyze (NSF, 1979). Unfortunately, no such analysis has resulted in a report, debate, and/or discussion. At the same time, there is great variety in terms of meaning, interpretatic., and needed action. The scientific community clearly calls for a return to the focus of the 1960's; those involved with science teacher groups hesitate to be critical of the findings and qualify their interpretations; parent groups are concerned with the meaning of science in general education, administrative groups look at broad issues; science educators provide some focus upon general curriculum models (such as Tyler's); generalist groups employ their own specialists to consider the meaning of new directions while pondering the current situation.

In addition to reviews by nine professional groups, in 1978 Norris Harms was awarded a grant to synthesize and to interpret the more than 2,000 pages of information from the three NSF status studies and the NAEP reports. The research effort was called "Project Synthesis" and involved a research team of 23 science educators throughout the U.S. The research team was divided into five focus groups--each charged with examining the components of K-12 science education. These focus groups represented the perspectives of biology, physical science, inquiry, elementary school science, and science/technology/society. Each group worked independently within the same framework. Four goal clusters and a series of elements for teaching (i.e., instructional procedures, teacher characteristics, instructional facilities and materials, and others) provided the structure for each of the five research teams (focus groups).

The general research procedure characterizing "Project Synthesis" was a discrepancy model which is used more frequently in the social sciences than in the natural sciences. Basic to this design is the promulgation of a desired state followed by descriptions of the actual state. This analysis, then, points the way to the critical third step--identification of the discrepancies between the two conditions. With the identification of such discrepancies, recommendations for future actions are possible.

The three NSF studies, the NAEP data, a review of current textbooks, and other analyses of the current situation in K-12 science provided a rich source of data for defining the actual state of K-12 science teaching in the U.S. in the late 1970's. The description of the actual state has been called a retrospective synthesis of information.

The prospective synthesis of information used for defining the desired state of science teaching may be more controversial. The information for this analysis was accomplished prior to a study of the surveys used to define the actual state. The information consisted of a wide variety of writings and reports concerned with current projects, viewpoints, and research. Some of the reports were derived from careful analyses of current indicators, needs, issues, and futuristic planning. Such a prospective synthesis is viewed by many as a qualitative and normative research procedure which is as valid and as productive as more traditional methods. Thus, a specific literature exists which deals with ideas, changes, thrusts, directions, and other forces which suggest needed directions for science teaching.

Discrepancies between "what ought to be" and "what is" are always expected. However, the identification of specific discrepancies provides both a direction and a framework for immediate action. A careful analysis of such discrepancies also provides a means for making professional recommendations.

The period of assessment and retrospection that began in 1976 was also evidenced by actions and concerns of the National Science Teachers Association, the largest professional organization in the world dedicated to the improvement of science education. The NSTA Board of Directors approved the creation of a special commission to review the current status of science education and to make recommendations for the next decade. Two and a half years later, after many debates and discussions by officers, executive committees, and boards of directors, and referral to various consultative and editorial groups, a Working Paper entitled, "Science Education: Accomplishments and Needs" (1978) was published by the ERIC Clearinghouse for Science, Mathematics, and Environmental Education (ERIC/SMEAC) which had funded many of the meetings and the general effort. Less than a year after publication of the report, NSTA (again with support from ERIC/SMEAC) authorized a major research effort concerning the major conclusions of the accomplishments and needs document (Yager, 1981).

The accomplishments and needs study involved 500 leaders in science education in 1980, including 100 of each of the following: elementary teachers, secondary teachers, supervisors, teacher educators, and researchers. These leaders were asked to rate and to comment upon (1) a definition and a setting for science education, (2) goals for science education, (3) accomplishments in science education, and (4) recommendations for the future or current needs in science education. This effort provides valuable information concerning problems, directions, needs, and disagreements within the profession. It expands the information base as the current situation in science education is analyzed; it identifies perceptions of the current leadership and provides a qualitative dimension to the NSF Status Studies and the Project Synthesis research effort.

The current period of assessment has also included other efforts to analyze the profession in terms of research, graduate programs, and current trends. Representatives from the 28 largest graduate centers for science education exchanged information regarding current problems and needed corrections. The group met in person in 1979 and authorized the production of a paper "Crisis in Science Education" (Yager, 1980a). This paper and the earlier statements of problems and solutions in science education were subsequently published as part of the Technical Report Series in Science Education at The University of Iowa. A small contract was awarded by NSF as a part of this assessment effort to study the status of science education in graduate centers. The study focused upon the 35 largest programs providing information regarding program features, budgets, faculty, support staff, and scholarly productivity during a 20-year period, 1960-80 (Yager, 1980b). Such assessment activities have recently been expanded to include a study of the State Departments of Education, all teacher education programs in the U.S., and corollary efforts at the international level. Preliminary information from these efforts suggests parallel trends, accomplishments, and recommendations for the current situation in science education.

All of the information which has been collected since the first report of one of the NSF Status Studies in 1977 suggests that a crisis exists in science education at the current time. This situation was evidenced by President Carter's 1980 request to the Director of the National Science Foundation (NSF) and the Secretary of the Department of Education (ED) for specific information regarding thrusts of science education. The President essentially declared a national emergency with respect to science and engineering education in the U.S. The report that the ED and NSF staffs prepared for the President was entitled, "Science and Engineering Education for the 80's and Beyond" (1980). It utilized the NSF Status Studies, the Synthesis analyses, and other available indicators. The report called for renewed attention to science and engineering education and described the problems and solutions as more demanding than the situation which stimulated great public support for science education late in the 1950's.

But the situation changed drastically in January 1981 with the inauguration of President Reagan. As a part of the effort to reduce government spending, to control inflation, and to relinquish federal control of certain functions, the Office of Management and Budget recommended abolishment of the NSF Science Education Directorate and deep cuts in the appropriation for the new Department of Education. Instead of significantly greater support as recommended by the Carter administration to solve a national emergency, suddenly there was to be no support.

If we were content with a historical perspective only, this would be the current situation in science education. It would leave us with questions and uncertainties concerning all of the input areas from Tyler's model. It would leave us in a state of confusion with respect to general curriculum objectives in science. However, the extensive assessment efforts during the years 1977-81 provide much information that should be used during the years remaining in the Twentieth Century.

The next three parts of this analysis will consist of a summary of the actual status of science teaching, as elaborated by the Project Synthesis researchers (Harms and Yager, 1981); a similar summary of the current situation, as presented in the Accomplishments and Needs analysis (Yager, 1981); and recommendations for science education for the future that come from both the preceding studies. These three parts will provide an accurate view of our current situation--a view made possible because of the five years of study and assessment that have occurred. Such assessment and analysis have rarely occurred at any point in the past. For that reason there is optimism that future actions can be based upon information, experience, and evidence rather than upon single pressures of a moment in time.

## ACTUAL STATES OF SCIENCE TEACHING

The Project Synthesis research team struggled with the components of Tyler's model for curriculum and instruction as the effort was conceived and proposed for funding. General objectives for school science were used throughout the process as organizers for analyzing the Status Studies and the NAEP information for determining the actual states of science teaching. These objectives were used as philosophical/sociological information was added to identify a more desired state for science teaching.

Philosophic perspectives in the field of education are usually embodied in statements regarding the broader aims and purposes of education. One of the first tasks of the Project Synthesis staff was to identify in very broad terms the most basic goals of science education. An attempt was made to state these basic goals in such a way that one could evaluate the effectiveness of the various elements of the science education enterprise that could address each goal. In order to perform this task, a number of articles and publications discussing goals, rationale, or philosophic perspectives in science education were identified. The goals were then sorted into a limited number of goal "clusters" which embodied the primary aims of science education as well as could be determined from existing literature. For the special purposes of Project Synthesis, the goal clusters used met the following criteria:

1) As a set, good clusters needed to be broad enough to capture the important, generally accepted goals of science education.

2) In both terminology and content, goal clusters needed to have meaning for many audiences, including those unsophisticated in science and in education.

3) As a set, goal clusters needed to be "unbiased." There had to be at least one "goal cluster" with which any particular person could identify. They could not be "our" goals, but rather an organization of "the" goals of science education.

4) The goal clusters had to be limited in number.

5) Each cluster needed to have some important unifying feature and to be distinct from other clusters in some meaningful way. (This does not imply mutual exclusivity, which is probably impossible.)

6) Goal clusters had to lend themselves to operational definitions in terms of student outcomes and elements of practice in science education.

7) Goal clusters had to differ from one another in ways which translate into some differences with respect to the operational definitions mentioned in 6 above.

8) At the end of the study, the goal clusters had to lend themselves to policy-relevant statements.

The term "goal cluster" was used throughout the process. This term reflected the reality that it is impossible to embody all the major goals of science education in a few short statements, but that it is indeed possible to characterize broad goal areas by relatively brief descriptors, useful in discussing major emphases in science education. The goal clusters used in Project Synthesis were determined jointly by the project staff and the leaders of the five focus groups, with useful input from Dr. Bentley Glass and Dr. David Hawkins who participated in the first meeting of group leaders. The goal clusters finally used divided learning outcomes into categories of relevance for (1) the individual, (2) societal issues, (3) academic preparation and (4) career choice. An elaboration is presented as a means of providing a more exact frame of reference for the effort:

Goal Cluster I: Personal Needs. Science education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world.

Goals that fall into Category I focus on the needs of the individual. For example, there are facts and abilities one needs in order to be a successful consumer or to maintain a healthy body. One should have some idea of the many ways science and technology affect one's life. Knowing that is still not enough. Science education should foster attitudes in individuals which are manifested in a propensity to use science in making everyday decisions and solving everyday problems.

Goal Cluster II: Societal Issues. Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

Category II goals relate to the needs of society. They pertain, for example, to the facts and skills a person needs to deal with the environmental and energy issues which affect society at large. In order to vote intelligently on science-related societal issues or participate in responsible community action, not only are specific facts and skills important, but also an understanding of the role of science in society, a knowledge of issues and how science relates to them, and a recognition that in providing the solution to one problem science can create new ones. Of course, to develop informed, concerned citizens and wise voters, science education also must be concerned with attitudes. It must instill in students a sense of responsibility, an appreciation of the potential of science to solve or alleviate societal problems and a sense of custodianship to protect and preserve that natural world with which science concerns itself.

A common element of personal and societal goals is the importance of the applications of science to problems of personal and societal relevance. In order for students to be able to apply to such problems, it is necessary that they have an understanding of the problems, of the aspects of science which apply to the problems, and of the relationship between science and these problems. Students should also have experience in the processes of applying science to the solutions of such problems.

Goal Cluster III: Academic Preparation. Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.

Goals in this category pertain to scientific ideas and processes which form a part of the structure of scientific disciplines, which may not be related easily to specific decisions about one's own life or about societal issues, yet which are necessary for any further study of science.

Goal Cluster IV: Career Education/Awareness. Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

Science classes in all disciplines and at all levels which prepare students to make informed career decisions regarding jobs related to science and technology would logically place emphasis on a variety of topics and learnings. These should include awareness of the many possible roles and jobs available in science and technology (including such careers as scientists, engineers, technicians, equipment designers, computer programmers, and laboratory assistants) as well as in jobs which apply scientific knowledge in such areas as agriculture, nutrition, medicine, sanitation, and conservation. Such learnings should also include: awareness that persons of both sexes, all ethnic backgrounds, wide-ranging educational and ability levels, and various handicaps can and do obtain such jobs, and awareness of the contributions persons in such jobs can make to society as a whole. Science studies should also include knowledge of the specific abilities, interests, attitudes, and educational preparation usually associated with particular jobs in which individual students are interested; a view of scientists as real people; a clear understanding of how to plan educational programs which open doors to particular jobs; and a recognition of the need for science, mathematics, and language arts coursework, as well as a broad base in the social sciences, to understand better the relationship between science and society. Students should also attain a knowledge of human and written sources for further information in all areas included in this goal cluster.

The Synthesis researchers utilized Tyler's model as their analyses were conducted. For example, the following observations were made as the study process occurred:

> Once a determination of broad goals is made, it is possible to describe specific student outcomes and curricular characteristics consistent with those goals. This is a very difficult step, probably because few are used to doing it.
>
> Different goals do, in fact, translate into different kinds of course offerings, text materials, teacher requirements, and classroom practices.
>
> The translation of various goals into operational terms makes possible the evaluation of how well educational programs are meeting each of the various goals.
>
> The intellectual process of carefully and thoughtfully translating broad goals into educational outcomes often has a significant effect on the way everyone views educational programs. (Harms and Yager, 1981, pp. 113-114).

There was a large degree of consensus within and among the five focus groups of Project Synthesis as to the general status of science education. Several generalizations emerged which reflect the conclusions of all focus groups, which are supported in various ways by all components of the data base, and which appear to cut across curriculum materials, course offerings, enrollments, teacher characteristics, classroom practice and student outcomes. They are discussed below.

I. At all levels, science education in general is given a relatively low priority when compared with the language arts, mathematics and social studies, and its status is declining. This low priority results in a general lack of support for science in most school systems. (Harms and Yager, 1981, p. 114).

As reported by the Inquiry Group:

> It was clear from the various data sources that not only the quantity, but also the nature of science education which occurs in the classroom, is heavily dependent on the large context in which education takes place. One important factor is the general esteem which the school and community hold for science generally. The evidence available in the studies reflects a positive view of science in schools and among those influencing schools. Nearly all teachers and counselors, school superintendents, and parents recognize the need for minimal competency in science (Harms and Yager, 1981, p. 114)

However, there do not appear to be strong forces working to promote science education (Stake and Easley, 1978). School superintendents do not appear to give science high priority (Stake and Easley, 1978); state science requirements are declining (Helgeson, et al., 1977); and there is some evidence that science education is being displaced by emphasis on areas such as the back-to-basics movements and vocational education (Stake and Easley, 1978). The lack of support often results in budget limitations which negatively affect the practice of science education. "In many locations, real money available for non-salary expenditures is dropping and the 'share of the pie' available for science has been declining as more budget pressure is being exerted by other needs, such as career education and special education" (Helgeson, et al., 1977, p. 122; Stake and Easley, 1978, 19:25-26). About half the superintendents and science supervisors felt budget cuts had seriously affected the science curricula (Stake and Easley, 1978).

II. Textbooks play a dominant role in science education. (Harms and Yager, 1981, p. 115).

The focus groups were generally convinced by the data sources that textbooks exert an overwhelming dominance over the science learning experience. Evidence to support this conclusion was apparent in all the data sources. The Case Studies found that teachers rely on texts (Stake and Easley, 1978), reported data that 90 to 95 percent of 12,000 teachers surveyed indicated they used texts 90 percent of the time (Stake and Easley, 1978), and summarized a number of points by saying:

> Behind every teacher-learner transaction . . . is an instructional product waiting to play a dual role as medium and message. They commanded teachers' and learners' attention. In a way, they largely dictated the curriculum. Curriculum did not venture beyond the boundaries set by the instructional materials. (Stake and Easley, 1978, 13:66).

Because of the dominant position textbooks hold in determining learning experiences, an analysis of "widely used texts" became an important step in determining the status of science education. The Biology, Physical Science, Elementary and Science/Technology/ Society focus groups each reviewed a number of textbooks found by the Weiss survey to be used most widely (Weiss, 1978). Generally they were inspected to determine if they reflected the desirable program characteristics as identified by the Prospective Synthesis which was mentioned intitially and which is discussed later.

III. Of the four goal clusters discussed earlier, only the goals related to development of basic knowledge for academic preparation receive significant emphasis. Goals related to personal use of science in everyday life, to scientific literacy for societal decision-making, and to career planning and decision-making are largely ignored. (Harms and Yager, 1981, p. 115).

The nature of the most widely used texts provides strong evidence for this conclusion. Generally, the most widely used texts in all disciplines at all levels were largely devoid of the characteristics representative of goals related to personal utility, societal issues, and career choice, as defined by the four focus groups. Although there was some rhetoric on the importance of such goals in the preface of some of the textbooks, there was notably little treatment of topics such as those identified by the focus groups as being representative of those three major goal areas. There was virtually no treatment of the relationship between traditional science concepts and the personal, societal, or career-choice decisions facing students, nor was there any substantive treatment of technological developments.

To illustrate the nature of the curriculum as exemplified by most widely used textbooks, an example of the kinds of things that were sought and the kinds of things found may be helpful. Consider, for example, the topic of insects. The typical high school biology course available to the majority of student includes a unit on insects. Some examples of possible learnings about insects which were looked for because they seem particularly useful in people's everyday lives include: the value of insects in yards and gardens (e.g., bees pollinating fruit trees, various insects eating other harmful insects); the damage done by insects in homes and gardens; ways of detecting this damage; and ways of controlling the harmful insects without endangering useful insects, pets, or individuals. Learnings which reflect the goal of societal relevance include: the economic impact of insects on food supplies; the health threat posed by ticks, malaria-carrying mosquitos, and other insects; the apparent necessity for the use of insecticides in intensive agriculture, the harmful environmental side effects of insecticides, and the consideration of trade-offs between these two factors in making decisions about banning or endorsing the use of insecticides. Also important in understanding the interface between science, society, and technology is knowledge of the development of new technologies which control insects (such as releasing sterile males). Career awareness activities related to the topic could reflect a wide variety of jobs from insect exterminators to entomologists who specialize in forest management. However, when the most widely used biology textbooks are reviewed, topics such as these are mostly ignored. What is found is a chapter which places insects taxonomically as arthropods. It goes on to devote the major part of the chapter to naming kinds of insects and describing in great detail the body parts of insects, especially the grasshopper. The scientific names of the many parts of insects are presented.

A short section on the behavior of social insects rounds out the chapter. There is virtually no attempt to associate insects with the experiences of the students, to prepare students to deal with insects in their daily lives, to understand the important societal issues involving insects in their daily lives, or to understand the important societal issues involving insects, their control, and the side effects of such control.

This example was as representative of most of the junior high texts reviewed by the Synthesis team as it was of the senior high texts, in the physical and earth sciences as well as in biology. It was a common experience in reviewing these texts to note places in the textbooks where it would be logical and easy to integrate information or activities relevant to the personal, societal, or career-choice goals, but this was virtually never done. Such an integration could, for example, take the form of real-world examples and references relating basic concepts to societal issues. Often, one sentence or a short paragraph strategically inserted would achieve much in this direction. The failure to make such insertions was considered as evidence that the ignored goals were given virtually no priority by those who prepared these popular textbooks.

Some textbooks do present fundamental knowledge in a more useful form. This was generally characteristic of the materials developed with NSF funds. For example, the BSCS "Green" textbook discusses insects in terms of their environment and ecological functions. However, it still ignores the kinds of topics exemplified in the "insect" discussion above. Widely used physical science texts developed by national program developers for use at the junior high level have made great strides in attention to concept development and inquiry skills, but they place no more stress on personal, societal, and career-choice goals than do other commercially available texts. For example, two widely used texts in this category, Introductory Physical Science and Probing the Natural World/2, are dedicated almost exclusively to development of concepts of force, motion, energy, a particle model of matter, and chemical reactions, all of which appear primarily for academic interest when not applied to common problems and phenomena.

It is important to note here that the Synthesis researchers were speaking of widely used texts, as determined by the Weiss survey. It is possible that a thorough review of all materials available would identify textbooks with much broader goals. The Elementary Group surveyed three categories of textbooks. The first category, "widely used texts," fits the general description state above. A second category of "NSF funded curriculum" and a third category of "new generation" texts are also identified and discussed in their report. These other two categories of textbooks, although not widely used, were considered by the Elementary Group to meet their criteria considerably better than those widely used in 1976. The Biology Group also identified a number of texts written for general use at the college level which provided much better treatment in the personal and societal areas, and some of these books appear to be no more difficult than commonly used high school textbooks. The science Technology Society Group also identified materials dealing with technology concepts, but found that they were virtually unknown to science teachers.

Although space here does not allow a treatment of laboratory practices, testing, course enrollments, and other characteristics of science education, there was clear evidence in the data concerning all the areas that the academic preparation goal dominates all aspects of practice. For evidence leading to this conclusion, the reader is referred to Volume III of the NSTA monograph, What Research Says to the Science Teacher, and to the full final report of Project Synthesis to NSF (Harms and Yager, 1981; Harms and Kahl, 1980).

IV. Teachers make most of the important decisions about course content, text selection, and instructional methods, and in so doing they determine the goals pursued by science education. (Harms and Yager, 1981, p. 117).

Teachers appear to be the primary decision makers in the selection and use of curricular materials (Weiss, 1978); teachers' involvement in this process, either as individuals or as part of selected committees, is far heavier than that of district supervisors, principals, or superintendents. School boards, parents, and students are virtually never heavily involved in selection of materials (Weiss, 1978). According to the Inquiry Group,

> Not only do teachers make the ultimate decisions about the nature of the science they teach, they rely heavily on other sources of information about new developments. When asked what sources of information about new developments were most useful, teachers at the primary, elementary, and junior high levels ranked other teachers above all other sources listed. At the senior high level, however, journals and college courses were ranked above teachers as sources of information (Weiss, 1978 p. 152).

This does not mean that all teachers have the opportunity to make unilateral decisions about the materials they use, since such decisions are often made by representative committees at the school or district level. However, there was considerable evidence that most teachers have autonomy in the way they utilize those materials to teach science (Stake and Easley, 1978). "Almost every science teacher had strong ideas as to how the 'basics' in science would be defined . . . and these ideas were continuing to be the prime determinant of what went on in the teacher's classroom" (Stake and Easley, 1978, 12:5). This autonomy apparently encompasses teaching style; modes of presentation, selection of texts, assignment of grades; and, within the limits set by the administration, the determination of such things as out-of-school field trips and work experience.

One striking observation is that the factors which affect teacher decisions about day-to-day practice do not appear closely related to the issues defined by the Synthesis researchers or those outlined in Tyler's curriculum and instruction model. That is, the ultimate utility (or lack thereof) of science knowledge and skills do not appear to be central guides in determining teaching practices. Rather, a number of important factors determining practice were seen by the Case Study observers as fitting within the general class of "socialization" (Stake and Easley, 1978). Socialization goals include inculcating students with the work ethic, teaching students to learn from a textbook, paying attention to directions or presentations, carrying out assignments, preparing for tests, preparing for next year, observing the mores of the community, respecting authority, competing, and cooperating.

Turning attention from the socialization goal to goals representative of the four goal clusters and inquiry teaching, it is possible to come to the firm conclusion that most teachers have a narrow perception of their responsibilities within these goals. The apparent primary goal of most science teachers appears to be that of teaching "fundamental knowledge" which is necessary to prepare students for later coursework. Goals related to preparation for using science in the personal, societal, and career-choice arenas, and goals related to inquiry appear to receive very little attention from teachers. The strongest evidence for this conclusion is the almost total reliance on textbooks, the nature of the textbooks themselves, and the fact that teachers choose these textbooks from the wide variety available.

Information about the current status of science education has important implications for change at the district, school, and classroom levels. Major shifts in educational needs require shifts in educational goals for many students. These shifts in goals can be achieved only if translated into new educational programs. Such program changes will probably require new objectives, new course offerings, new or revised materials, and a redefinition of teacher responsibility.

## CURRENT ACCOMPLISHMENTS AND NEEDS

The NSTA Accomplishments and Needs study was divided into four major sections. These included (1) a setting and a point of departure for the discipline of science education, (2) the aims for science education, (3) an analysis of the current status of science education with a focus on the accomplishments, and (4) recommendations for future actions for meeting needs in science education.

The interdependence of science and society was identified as the appropriate setting for any consideration of science educaton. There is now agreement that science education is in and of itself a young discipline concerned with the interface of science and society. It is concerned with the interpretation of science to society, especially learners; it is equally concerned with interpreting and studying the effects of society upon science. This setting for an analysis of the accomplishments and needs for science education in the 80's is new, at least to the extent that there is agreement among all levels and functions of the current leadership. There was strong agreement among many groups that a consideration of current societal problems and issues should provide the most significant influence upon science teaching at all levels for the 1980's. Such a frame of reference provides new meaning for the initial input in defining general objectives for curriculum and instruction with Tyler's model.

Helgeson, Blosser, and Howe (1977) reported that the goals of secondary science education were in major transition in 1977, the time of their NSF Status report, as viewed from an analysis of the research literature. The NSTA analysis team agreed that goals were in transition when the working draft was prepared. The leadership in science education in 1980 also generally agreed that significant transitions were occurring. Only one sampled group, the teacher educators (AETS membership), showed less than majority agreement. Supervisors and researchers were most emphatic concerning their perceptions of change in goals (general objectives as per Tyler's model).

The science education leadership was in general agreement as to the direction for such changes in goals. Most saw a focus on the science and society interface, the use of science in daily situations, value and ethical dimensions for science, and an emphasis on problems and the future as new kinds of emphases for school science.

While the period of transition and general agreement about the nature of such new goals were noted, many among the leadership emphasized the continued importance of basic concepts and central process goals. There was general agreement that the current situation with respect to goals was not a major disconformity with the immediate past. In fact, there was general agreement that the goals of science education have been fairly stable among advocacy groups for the past 40 years. Does this constitute a paradox? Goals have been (and to some extent are) stable, and yet we are in a major period of change with respect to goals. There is also strong agreement within the profession that change with respect to all aspects of science teaching is desirable and to be expected. Change with respect to goals, curricula, and teaching strategies is inherent to science iteself. In a sense, there is agreement that the curriculum and instruction model proposed by Tyler represents a continuous process.

The analysis of the current status of science education suggests the importance and success of the science curriculum efforts of the 60's. There is general support for the notion of continuing needs with respect to staff development while suggesting that the NSF efforts of the 60's did little with respect to changing teacher behavior. They did expand the subject matter competency of teachers and provided familiarization with newly developed materials. The importance of the teacher in the teaching/learning process was noted and emphasized.

Several facts and/or occurrences are identified as important considerations as one analyzes the current situation and reviews the accomplishments and failures of the immediate past. Some of these factors include major sifts in population in the U.S., major decline in the support for science instruction (and schooling in general), enrollment declines in schools and in science courses, a focus on accountability and competency-based programs, students vastly different from those of previous times, and teacher unionization. Such sociological/societal factors seem more important then ever before in discussing the current situation in science teaching--both as to the accomplishments and continuing needs.

The major portion of the accomplishments and needs report was concerned with specific recommendations for the future. Twenty-five specific recommendations were selected for use in studying the level of agreement among the current leadership in science education for specific actions. Generally there was strong support for the recommendations, with slight variations in terms of support among various groups of teachers, supervisors, teacher educators, and researchers.

Some of the specific accomplishments in science education during the past two decades which were identified include:

1) Major involvement of the scientific community in defining the disciplines of science, in interpreting latest discoveries that are important as preparation for future living, and in participating as a part of curriculum development teams.

2) New views of science education that include philosophical, historical, sociological, technological, and humanistic dimensions; recognition that these new views are as valid as organizers for learning experiences as are content and process schemes.

3) National concern for and interest in better science experiences for American's youth; renewed interest in science for all people.

4) Development of new materials which can be adapted to local situations; new instructional strategies with model materials to implement them.

5) Massive efforts to affect science curricula and teacher in-service programs

6) Excellent preparatory sequences to enable students to prepare for advanced careers in science and technology.

7) Improved materials and facilities for appropriate science instruction.

Some of the major needs for future years include:

1) A new conceptualization of science education as a discipline; a reformulation of goals to meet the needs of a new society.

2) In-service programs to assist professionals with implementing programs consistent with new goals.

3) Continued curriculum development to assure models for implementing new philosophy and new teaching strategies.

4) New programs for assessing all aspects of instruction and learning to provide information for planned changes and improvements.

5) New cooperative enterprises involving all segments of government, industry, and community groups, as well as persons from all levels of the professional science education community.

6) New support systems, including personnel, learning centers, and communication links, to encourage change and professional growth.

7) New philosophical bases for research in order to test the validity of new conceptualizations and new directions.

Generalizations arising from the analysis of the Accomplishments and Needs study include:

1) Most of the specific points identified by the original writers are points with which most of the science education leadership groups agree. These points include (a) a societal setting or framework for science education, (b) the emergency of new goals for science teaching, (c) some specific accomplishments in the area of curriculum development and the improvement of instruction, and (d) an extensive listing of recommendations for the future.

2) Although there was much agreement regarding the major points in the original report, there was a general lack of enthusiasm for the writing, the organization, and the poignancy of the message. Many see an urgency for (a) new framework/domain statements, (b) new statements of aims and goals, (c) more precise reflections upon past accomplishments, and (d) more focused recommendations for action.

3) There is much evidence that various groups within the discipline of science education represent severe divisions which affect professional vitality, the ability to work as parts of a total team, and easy communication within the profession and with the rest of society. There is general agreement concerning (a) the urgency of the current situation, (b) the need for cooperation, and (c) the necessity for action.

Specific areas where agreement and direction are noted include:

1) Emphasis upon science for academic preparation has been a major focus of the past. However, major concern for science as a means of encountering and resolving current societal problems, as a means for attending to the personal needs of students, and as a means of approaching greater awareness of career potential in science, technology, and related fields suggest goals that may be far more important than the traditional goal of academic preparation for future courses.

2) Teachers are central in realizing past accomplishments, in planning local programs, and in making the difference with learners. Curriculum is seen as a form of support for teachers--not something that will constrict and/or direct them. The necessity for improving teacher education programs (both pre-service and in-service) is viewed as a critical need and one where there is greatest agreement across the profession concerning the need.

3) Some of the past assumptions regarding science teaching are being questioned. These include:

   a) The importance of the laboratory--(a redefinition of laboratory in terms of position in the program is occurring);

   b) the appropriateness of inquiry as a focus;

c) the "discipline" organization for secondary courses;

d) a two-dimensional view of science (i.e., content and process) as accurate and/or complete;

e) a focus upon science that is at the "cutting-edge" of researchers (science that is useful in the lives of learners is in evidence);

f) the necessity of science as a precursor for study at the next academic level;

g) the appropriateness of all learners learning the major ideas and the unique processes that professional scientists know and use; and

h) the more science content preparation that a teacher experiences, the better the teacher.

4) Continued questioning, assessment, evaluation, and specific new attempts with goals, curriculum, teaching strategies, and support materials and personnel are important as a means for stimulating improvements and for solving many immediate problems. This basic "spirit of science" must be used to a greater degree in science education.

5) There is an urgency concerning the current status of science education in the United States. There is general agreement that science education must act in a concerted fashion in order that educational and societal problems might be confronted and resolved.

## TOWARD A NEW DIRECTION

Many of the reports and analyses which have appeared during the past three years suggest common new directions for the discipline of science education. There has been major input from a variety of sources for determining new general objectives. There is much more known about philosophical/psychological/sociological dimensions to permit the formulation of new instructional objectives which can in turn be used to select and organize learning experiences. A new analysis designed to summarize such advances in a variety of fields has just been completed and is available for use, as Tyler's model for curriculum and instruction provides the framework for action once again.

The NSF and ED report "Science and Engineering Education for the 1980's and Beyond" (1980) identifies specific needs and directions. A Section Q report to the American Association for the Advancement of Science (AAAS) Board of Directors entitled "Perspectives on Science Education" (Watson et al., 1979) is another attempt at a statement of new direction. The 1980 "Crisis in

Science Education" report cited earlier (Yager, 1980a) ended with a section on indicators for the future that could ameliorate the "crisis". The NSTA Accomplishments and Needs report and the 1981 analysis of it emphasized continuing needs and desired actions.

Perhaps the most comprehensive effort at defining a desired state for science education was conducted by the Project Synthesis research team. They accomplished a prospective synthesis of desired science education based upon analyses of a wide variety of writings and reports concerned with current projects, viewpoints, and research. Some of the reports were derived from careful analyses of current indicators, needs, issues, and futuristic planning. Depending upon the specificity and the nature of the final product, this process can be viewed as an example of Tyler's model for curriculum and instruction in use. The results of such an action can provide new models for piloting new approaches, new criteria for assessing current programs and practices, and new rationale for school science.

Because of the magnitude of the Project Synthesis effort, the new directions described will focus upon the Desired State that was developed as a part of that project. This prospective synthesis is presented as a qualitative and normative research procedure with much potential in curriculum development--in a sense, an expansion and elaboration of Tyler's model.

The Synthesis researchers utilized several critical factors as they formulated the desired state for science teaching. These provided one dimension in addition to the conceptual themes, the process skills, the goal clusters, and the social indicators. Five critical areas from Tyler's curriculum/instruction model are selected to summarize the desired states for science teaching. The features of an exemplary science program include the following:

a) Goals. An effective science program for the 80's will utilize the human being, human potential, human advances, and human adaptation as organizers. Alternative futures will be a desirable focus. Too often there is little or no emphasis in current programs upon the human and his/her environment. A second goal for an effective program will be the utilization of current problems and issues as organizers; currently there is only marginal emphasis upon such goals. A third goal is concerned with processes. Effective science programs will emphasize those processes that can be used. In the past, inquiry skills have emphasized processes that scientists use. A fourth goal suggests the importance of practice with decision-making skills involved with using scientific knowledge in a social context. Too often the current emphasis in science classrooms is upon skill for and practice with uncovering correct answers to discipline-bound problems. A fifth goal is in the area of career awareness. Such considerations should be an integral part of learning, not incidental. In current programs such attention to careers is usually limited to highlights of historical personages only. A sixth goal deals with value, ethical, and moral considerations. In the desired program these are important areas when dealing with problems and issues. At present, science is too often taught as value-free and discipline-bound concepts and activities.

b) Curriculum. The curriculum should be problem-centered, flexible, and valid in terms of current culture and current science. At present the science curriculum is textbook-centered, inflexible, and only valid in a classical scientific sense. The science curriculum also should include the human as a central ingredient. At present, humankind is only incidental in the curriculum. There almost seems to be a conscientious effort to make science inhuman and antiseptic. Another feature of a desired curriculum is that it is multifaceted, with a local and community relevance. Currently, the curriculum is textbook-controlled where local relevance is fortuitous. Use of the natural environment, community resources, and current concerns also should be foci for study. At present, contrived materials, classroom-bound resources, and commercially prepared manuals are used almost exclusively. A final feature of the desired science curriculum is the view of scientific information that can be used and applied by students in a cultural/social environment. At present, the science information is presented in a context which considers only the logic and structure of the discipline.

c) Instruction. First of all, instruction should be individualized and personalized, recognizing student diversity in a desired program. At present, group instruction is the mode, and it is geared to the average student and directed by the organization of the textbook. A second feature of desirable instruction is emphasis upon cooperative work on problems and issues. In most science classrooms there is little group work, and it is often in the laboratory which deals mostly with verification-type activities. A third feature of a desired instructional mode is that it be based upon current information and research in the area of developmental psychology. Most current procedures arise from weak psychological bases; most that do exist are from a behavioristic orientation.

d) Evaluation. Testing and evaluation should stress the use of knowledge to interpret personal and social problems and issues. At present, testing and evaluation are based upon replication of assigned information. Another feature of a desired evaluation program is its concern for growth in rational decision-making strategies. In too many current classrooms students are merely expected to state "correct" solutions to preplanned problems.

e) Teachers. Teachers need to have some specific characteristics for the kind of desired science education which has been synthesized. Teachers need to develop a commitment to human welfare and progress. Such philosophical perceptions are not commonly evident in current practices. The only observable commitment on the part of science teachers is one of commitment to science as a discipline. The desired science program requires teachers with new philosophical positions since such positions affect goals, curriculum, and teaching practices from an a theoretical base--one like they themselves experienced.

The differences between the actual (what is) and the desired (what should be) states of science teaching are summarized as follows:

| DESIRED PROGRAM | ACTUAL PROGRAM |
|---|---|
| **Goals:** | |
| 1. Human adaptation and alternative futures emphasized | 1. Minimal consideration given human adaptive capacities. |
| 2. Scientific problems and issues as goals | 2. Marginal emphasis on science-related goals |
| 3. Inquiry processes unique to scientific disciplines | 3. Inquiry skills characteristic of a generalized model of science |
| 4. Decision-making involving scientific knowledge in contexts | 4. Uncovering a correct answer to discipline-bound problems |
| 5. Career awareness an integral part of learning | 5. Minimal attention to careers, historical personages high |
| 6. Value, ethical, and moral considerations of science-related problems and issues | 6. Value-free interpretations of discipline-bound problems |
| **Curriculum:** | |
| 7. Curriculum is problem-centered, flexible, and culturally as well as scientifically valid | 7. Curriculum is textbook-centered, inflexible; only scientific validity is considered |
| 8. Humankind central | 8. Humankind incidental |
| 9. Multifaceted, including local and community relevance | 9. Textbook controlled; local relevance fortuitous |
| 10. Use of the natural environment, community resources and the students themselves as foci of study | 10. Contrive materials, kits, and classroom-bound resources; in biology use of sub-human species as foci of study |
| 11. Scientific information is in the context of the student as an organism in a cultural/social environment | 11. Scientific information is in context of the logic and structure of the discipline |
| **Instruction:** | |
| 12. Individualized and personalized, recognizing student diversity | 12. Group instruction geared for the average student and directed by organization of the textbook |
| 13. Cooperative work on problems or issues | 13. Some group work, primarily in laboratory |
| 14. Methodology based on current information and research in developmental psychology involving cognitive, affective, experiential, and maturational studies | 14. Weak psychological basis for instruction in the sciences; behavioristic orientation |

**Evaluation:**

| | |
|---|---|
| 15. Testing and evaluation stress the use of scientific knowledge to interpret personal and social problems and issues | 15. Replication of assigned information |
| 16. Student evaluation is based on growth in rational decision-making | 16. Stating "correct" solutions to pre-planned problems |

**Teachers:**

| | |
|---|---|
| 17. Requires a change in perceptions (philosophy, rationale, belief system) of science teaching to include a commitment to human welfare and progress | 17. Philosophical perceptions not evident in practice, beyond a commitment to the disciplines of science |
| 18. Philosophical position influences all aspects of curriculum and teaching practices. | 18. Curriculum and teaching practices largely atheoretical and routine. |

## SUMMARY ANALYSIS

There is not easy solution to the current problems in science education. To be sure, an important step toward a solution is the recognition of a crisis--its causes, its magnitude, its complexities, its seriousness, its meaning. Such recognition and such understanding can do much in moving the profession beyond the current situation.

In order to take advantage of the opportunity afforded by the crisis, we need to propose, to debate, and to use definitions of the domain for science education; such definitions should not be voted upon, agreed upon, or compromised. The definitions should be derived from our history and the contemporary situation in science, society, and education. They can, nonetheless, provide intellectual and scholarly contexts for actions within our field. We need to analyze, synthesize and, finally, utilize what we know about science teaching. This needs to be separated from the dogma which so often engulfs and governs what we do. We need to capitalize upon our successes with meeting past crises; since each age brings new challenges and new problems, we must look upon the current crisis as opportunity.

At this time of crisis in science education we need to show uncommon ability in viewing the common problems. First, we need to step above our own personal orientations, projects, and problems and focus on the generalized needs of science education. Science educators must be aware of the philosophy, history, and sociology of science; be acquainted with cultural and societal forces which cause changes; be knowledgeable of the conditions which promote the finding of new knowledge; and be able to utilize such knowledge for the advancement of the profession. Further, science educators need to discuss rationales, to identify new goals, and to plan for the next vital steps for our discipline. We need massive response and action to a major crisis.

There is indeed an urgency to the problems confronting our discipline. By every report, factual and intuitive, we are at another historical turning point. If nothing is done, if no changes are made, the field of science education no doubt will suffer further deterioration. However, there is the possibility of going beyond the crisis to a period of restoration in science education. This is our challenge for the future.

As we review the current situation it may be apparent that we are ready to utilize once again Tyler's model for curriculum development and instructional improvement. The Synthesis writers closed their report to the science teaching community in Volume III, "What Research Says to the Science Teacher" (Harms and Yager, 1981), with a set of imperatives which utilize the procedures suggested by Tyler. There is much to suggest the need for and the nature of new general objectives for science education. But the formulation of these goals is the most important step in facing our current problems.. The specific suggestions, in order of importance and in order of action, include:

1. A major redefinition and reformulation of goals for science education; a new rationale, a new focus, a new statement of purpose are needed. These new goals must take into account the fact that students today will soon be operating as adults in a society which is even more technologically oriented than at present; they will be participating as citizens in important science-related societal decisions. Almost total concern for the academic preparation goal, as is currently the case, is a limiting view of school science.

2. A new conceptualization of the science curriculum to meet new goals; redesigns of courses, course sequence/articulation, and discipline alliances are needed. The new curricula should include components of science not currently defined and/or used in school. Direct student experiences, technology, and personal and societal concerns should be foci.

3. Needed are new programs and procedures for the preparation, certification, assignment, and continuing education of teachers; planned changes; continuing growth; and systems for peer support. With new goals and a new conceptualization of the science curriculum, teachers must have assistance if their meaning is to be internalized. Without attention to in-service education, new directions and new views of the curriculum cannot succeed.

4. New materials to exemplify new philosophy, new curriculum structure, new teacher strategies; and exemplars of the new directions (i.e., specific materials for use with learners) are constantly needed. They provide concrete examples for use in moving in such new directions.

5. A means is needed for translating new research findings into programs for affecting practice; a profession must have a philosophic basis, a research base, a means for changes to occur

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based on new information. Separation of researcher from practitioner is a major problem in science education. All facets of the profession must work in concert for major progress to occur.

6. Renewed attention to the significance of evaluation in science education, self-assessment strategies, questioning attitudes, and massing evidence for reaching decisions on instruction and student outcomes are basic needs. Without such questions, observations, and judgements, future changes will be merely haphazard occurrences.

7. Much greater attention to development of systems for implementation and support for exemplary teaching and programs at the local level is needed; current erosion of support systems for stimulating change and improvement in science education at all levels is a major problem.

Never have we had so much information to analyze as we define our current situation in science education. Never have the needs and directions been so clear. Never have the needs and challenges been greater. Never have the stakes been so high.

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PART II

# SCIENTIFIC LITERACY: THE DECISION IS OURS

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## INTRODUCTION

Why do we teach science in our schools? What constitutes a general education in science? These questions lie at the foundation of science instruction. Yet, few science teachers have considered the implications that answers to these questions have for the science instruction they provide our future citizens.

In this chapter, a rationale for teaching science as part of a general education to prepare scientifically literate citizens will be discussed. An attempt will be made to persuade science teachers that we have the professional responsibility and competence to direct science education toward that goal. It will be demonstrated that the curriculum design agenda explicated by Ralph Tyler (1949) in Basic Principles of Curriculum and Instruction can be adapted to the task.

## A LIBERAL EDUCATION AND SCIENCE

The ancients viewed education as a process of cultivating human excellence and, thereby, developing "good" citizens. The definition of a "good" citizen has changed since antiquity with the evolution of societies and political systems, but the view that the ultimate goal of education is to prepare individuals to be functional citizens still prevails.

In Democracy and Education, John Dewey (1916) reaffirmed the classical view of education when he argued that a liberal education is the most appropriate type of education for free men. A liberal education aims to develop one's powers of understanding and judgement, and so, turn out individuals who can exercise their political liberty in a responsible fashion. The arts and humanities have been part of a liberal education since medieval times. Today, we also include the natural and social sciences which offer as much to the development of our culture as do the traditional arts and humanities.

Within the framework of a liberal education, it is generally acknowledged that the purpose of a science education is to prepare citizens to function with science as it touches their everyday lives. A number of terms were coined during the late 1950's and early 1960s to describe that which every citizen should know, understand, feel, and do, to some extent, within the realm of science. Scientific literacy is the most widely used of these terms. Since the inception of the term, there have been a number of noteworthy attempts to define the concept of scientific literacy and so delimit who is scientifically literate.

## DEFINITIONS OF SCIENTIFIC LITERACY

Early-on in the evolution of the concept of scientific literacy, the definitions were almost as inapt as they were novel. Some early advocates of scientific literacy took the phrase literally, defining it in terms of one's ability to read and comprehend popular scientific literature, such as that found in Scientific American. Others held the view that scientific literacy could be developed merely by reading certain books on the nature of science (NEA Journal, 1973). Many defined scientific literacy using more nebulous phrases:

> . . . a comfortable familiarity with the development, methodology, achievements, and problems of the principal scientific disciplines. (p. 34)

> . . . scientific literacy is to a large extent a matter of feeling and of value. These feelings and values are expressed by such words as curiosity, accuracy, quality, persistence, wonder, awe, and reverence. These feelings of values, however, must be founded on a measure of knowledge and a desire to increase that measure. (p. 55)

> A person literate in science knows something of the role of science in society and appreciates the cultural conditions under which science thrives. He also understands its conceptual inventions and its investigative procedures (NSTA, 1964, p. 9).

While such definitions of scientific literacy captured the spirit of the concept, they in no way provided a means for objectively distinguishing scientifically literate individuals from those who were not. The intransitive verbs used in the definitions e.g., to be familiar, to appreciate, to understand) were fraught with ambiguity. As a result, the early definitions did not specify distinct, observable states or behaviors which characterize one who is scientifically literate. Yet, if scientific literacy was a goal of a science education, it was requisite that one be able to identify those who were scientifically literate.

The first step toward a behaviorally stated definition of scientific literacy was taken in 1964 at the Scientific Literacy Center at the University of Wisconsin. Pella, O'Hearn, and Gale (1966a, 1966b) searched 18 years of literature to identify common factors in definitions of scientific literacy. Pella's group noted that none of the 100 documents found to relate to scientific literacy described the phrase with any high degree of specificity. Nonetheless, he and his colleagues were able to glean six general referents from the documents, which led them to conclude that a scientifically literate individual has knowledge of the

> a) interrelationships of science and society, b) ethics that control the scientist in his work, c) nature of science, d) basic concepts of science, e) differences between science and society, and f) interrelationships of science and the humanities. (1966a, p. 206)

Hurd (1970) preferred the phrase "scientific enlightenment" to scientific literacy. He held that

> The broad goal of science teaching ought to foster the emergence of an enlightened citizenry, capable of using the intellectual resources of science to create a favor-able environment that will promote the development of man as a humane being. (p. 14)

Hurd enunciated his definition of scientific literacy in 12 statements which specified understandings and attitudes of a scientifically literate person. According the Hurd's discussion, a scientifically literate individual: 1) understands the purposes of the scientific endeavor; 2) recognizes that scientific knowledge grows progressively; 3) knows in a functional way some of the major concepts, hypotheses, laws, and theories of several different sciences; 4) appreciates the worthiness of systematic investigation in the sciences; 5) recognizes the interdependency of inquiry processes and the derived concepts, laws, and theories; 6) appreciates science for the intellectual stimulus it provides; 7) sees the need to view the scientific enterprise within the broad perspectives of culture, society and history; 8) appreciates the cultural conditions within which science thrives; 9) expects that social and economic innovations may be necessary to keep pace with and to enhance scientific and technological developments; 10) views science and technology as interrelated and dependent upon each other, yet not synonomous, 11) appreciates the universality of scientific endeavors; and 12) possesses an awareness of the need to generate a system of concepts within which science, society, and the humanities can fit.

In 1971, the National Science Teachers Association's Committee on Curriculum Studies:K-12 presented a position statement on <u>School Science Education for the 70s</u> to the NSTA Board of Directors. The statement was a synthesis of the views from 125 science educators toward the concentration and emphases of science instruction. In the statement, the development of scientifically literate and personally concerned individuals was identified as the major goal of science instruction. The committee believed that achieving scientific literacy involved the development of appropriate attitudes, competence with the process skills of science, and a functional knowledge of science concepts. These were laid out as 11 characteristics of a scientifically literate person. The scientifically literate person was described as one who

1. uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and his environment;

2. understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories;

3. distinguishes between scientific evidence and personal opinion;

4. identifies the relationship between facts and theories;

5. recognizes the limitations as well as the usefulness of science and technology in advancing human welfare;

6. understands the interrelationships between science, technology, and other facets of society, including social and economic development;

7. recognizes the human origin of science and understands that scientific knowledge is tentative, subject to change as evidence accumulates;

8. has sufficient knowledge and experience so that he can appreciate the scientific work being carried out by others;

9. has a richer and more exciting view of the world as a result of his science education;

10. has adopted values similar to those that underlie science so that he can use and enjoy science for its intellectual stimulation, its elegance of explanation, and its excitement of inquiry; and

11. continues to inquire and increase his scientific knowledge throughout his life. (1971, pp. 47-48);

Pella et al., Hurd, and the NSTA Committee on Curriculum mapped the gross anatomy of scientific literacy. The delineation of the finer structure in observable terms was taken up in 1974 by Victor Showalter and his colleagues at the Center for Unified Science Education in Columbus, Ohio. Showalter (1974) reviewed 15 years of relevant literature and derived from it seven dimensions of scientific literacy:

1. The scientifically literate person understands the nature of scientific knowledge.

2. The scientifically literate person accurately applies science concepts, principles, laws, and theories in interacting with his universe.

3. The scientifically literate person uses processes of science in solving problems, making decisions, and furthering his own understanding of the universe.

4. The scientifically literate person interacts with the various aspects of his universe in a way that is consistent with the values that underlie science.

5. The scientifically literate person understands and appreciates the joint enterprises of science and technology and the interrelationships of these with each other and with other aspects of society.

6. The scientifically literate person has developed a richer, more satisfying, and more exciting view of the universe as a result of his science education and continues to extend this education throughout his life.

7. The scientifically literate person has developed numerous manipulative skills associated with science and technology. (p. 1:2)

Each of these dimensions of scientific literacy was further specified by stating and describing several factors which comprise it. For example, the factors under dimension 1 are nine one-word descriptors (i.e., tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic, empirical) with paragraph-size explications which characterize the nature of scientific knowledge (p. 1:2-3). The factors under dimension 2 are key concepts of science ". . .that are pervasive throughout the various specialized sciences and, in effect, comprise the bricks from which conceptual structures (laws, principles, etc.) are built" (p. 1:3). Included among the factors are such concepts as cause-effect, change, cycle, energy-matter, entropy, equilibrium. . . . Those values identified in <u>Education and the Spirit of Science</u> (1966) by the Educational Policies Commission of the National Education Association as characterizing the scientific enterprise and rational thought are the factors listed under dimension 4 (p. 23).*

In contrast to the view that ~~scientific literacy is~~ either achieved or not achieved, Showalter presented each factor in his definition of scientific literacy as a continuum along which an individual can progress. He wrote,

> as an individual becomes more scientifically literate, he or she will understand this factor at ever increasing levels of sophistication and will be able and motivated to apply this understanding to a greater number and variety of real-life situations. (p. 1:2)

Thus, each of the definitions's factors can be used as sources for sequences of instructional objectives in science instruction development and evaluation over a wide range of grades.

> There are many ways the Dimensions of Scientific Literacy and their component factors can be used. Several of these ways, each of which is consistent with the intent of the effort that produced the dimensions, are:
> 1- As a basis for reviewing, rethinking, and revising local science program objectives
> 2- As a basis for evaluating the effectiveness of a current science program
> 3- As a basis for establishing program objectives to be used in developing a new unified science program
> 4- As a bank of core objectives from which selected components would be used as instructional unit objectives
> 5- As a springboard for science staff discussions directed to rethinking the reasons for having science in the school curriculum
> 6- As a source of instructional objectives for creative development of evaluation instruments. (p. 2:3)

* Copies of Showalter's definition can be obtained by sending a pre-addressed and stamped envelope to Dr. Victor Showalter, Center for Unified Science Education, Capital University, Columbus, OH 43209.

## OBSTACLES TO SCIENTIFIC LITERACY

Over the two decades in which science educators have wrestled with the problems of delimiting the concept of scientific literacy, the definition has evolved from statements which literally interpreted the phrase to the high degree of specificity entailed in Showalter's dimension-factor format. The explication of Showalter's definition eliminated what had been identified as the major obstacle to the attainment of a scientifically literate citizenry (Evans, 1970). Yet, it is tragically clear from public reactions to and dealings with recent science-related societal issues (e.g., the so-called Energy Crisis, the Three Mile Island incident, genetic engineering) that in 1982 we are a nation generally composed of scientific illiterates. Evans' description of the average citizen would still appear to be appropriate today:

> He is ignorant of science and quick to admit his ignorance. Such an attitude is certainly a major deterrent to scientific literacy. (p. 83)

Given the massive amounts of public support which engendered the unprecedented wave of science curriculum development, science teacher training, and school science enrollment increases during the 1960s, one is driven to ask, "How can this be the case? Was not progress made over the past two decades in educating the general public in science, in developing a scientifically literate citizenry?"

The science curriculum development efforts of the 1960s had as their aim the cultivation and pre-college training of a pool of potential scientists, engineers, and technicians. Attempts to develop science curricula which aimed at goals other than academic preparation in science came late in the decade and were smothered, for all practical purposes, by an anti-science backlash which surfaced during the early 1970s. These repercussions eventually led to withdrawal of federal support for the most science curriculum development and the accompanying science teacher in-service activities. The consequences of those events linger today. With few exceptions, the extant secondary science curricula singularly emphasize objectives related to the development of basic science knowledge. Objectives related to dimensions of scientific literacy which deal with the use of science in everyday life for personal/societal decision-making are largely ignored.

The Project Synthesis Report (Harms & Yager, 1981) on the current status of science education presents evidence that science teachers and science textbooks continue to be the determinants of science learning experiences. Science teachers, individually or in groups, traditionally have been the primary decision-makers in the selection of science textbooks. But, because science teachers tend not to venture beyond the boundaries set by these curricula, science textbooks, in actuality, dictate the nature and range of science learning experiences.

Given this state of affairs, there would appear to be but one chance that science instruction will soon transcend its conceptual orientation to become aligned with the much broader role science plays within modern society. Pressure in the market place by informed curriculum decision makers, science teachers, may well be the only feasible means for redirecting science instruction.

As we science teachers begin to select science curricula which pursue objectives that prepare citizens to deal in a responsible fashion with science-related societal issues or, in some cases, even locally develop instructional materials aimed at such purposes, textbook publishers will respond in kind to the market trend. There will soon exist a diversity of curriculum materials which approach the broader goals of science instruction.

Science teachers are more than curricular delivery boys. We have the professional competence and obligation to help determine the directions science instruction will take. We also have the financial power through consumer action to influence that direction. Our actions as curriculum consumers can be the key step toward attainment of a scientifically literate citizenry.

In Basic Principles of Curriculum and Instruction, Ralph Tyler (1949) describes a curriculum design model which science teachers can adapt to select science curricula consistent with the goal of citizen scientific literacy for a science unit, science course, or an entire science program.

## RELEVANCE OF TYLER'S MODEL

Tyler (1949) describes a four-step curriculum design rationale. By that agenda, (1) the curriculum design process begins with the translation of educational purpose into instructional objectives, (2) learning experiences are selected which are likely to be useful in attaining these objectives, (3) the learning experiences are organized into units, and (4) the effectiveness of the learning experiences is evaluated. The scheme presented by Tyler designates a comprehensive sequence of procedures for curriculum design tasks. Yet, as Tyler states, there are many situations in which the steps to be followed would differ from the sequence he presented (1949, p. 128). The selection of science curricula which are consistent with the goal of citizen scientific literacy is an example of such a situation. That process would necessitate application of the first two steps in Tyler's rationale: statement of objectives and use of these to select learning experiences. Both activities are within the range of duties taken on by a group of science teachers during the textbook adoption process.

### Statement of Instructional Objectives

In discussing the first step of his model, Tyler (1949) stresses the importance of having a clearly defined purpose prior to the statement of instructional objectives. An appropriate purpose or goal statement in the case of science curriculum selection for citizen scientific literacy would be the definition of a scientifically literate citizen. The science teachers in a department or school district working on textbook adoption could accept an existing definition of scientific literacy, adapt an existing definition, or construct one. In all cases, the dimension-factor structure which Showalter used is highly recommended for the ease it brings to the derivation of instructional objectives.

An example of a definition of scientific literacy which follows the dimension-factor format and which is similar to that which another group of science teachers might develop, is found in a science methods worktext prepared by Hungerford and Tomera (1977). By Hungerford and Tomera's definition,

> A scientifically literate human being can be described as one who. . .(1) . . . has a correct concept of what science is and what it is not. . . . Science is simply a special way of investigating the objects and events of the universe. It is based on a philosophy of what is reality and this philosophy dictates some rules that must be respected when man searches for scientific knowledge. A critical basis of science is its empirical nature. Empiricism is observation or experimentation oriented. And, similarly, knowledge can be empirical only if it can be replicated. This means simply that the observation of the experiment can be repeated and shown valid. Scientists also believe that man must consider knowledge to be tentative. The scientist perceives that knowledge is subject to change. Interestingly, children (and some adults too) believe that scientific knowledge has an absolute truth value. This is not the case at all! Most scientific knowledge is inductively derived knowledge and subject to change as a result of new observations. Much of what scientists "know" is constantly being modified as a function of new information.
>
> In addition, scientific knowledge is usually perceived as being probabilistic. Here, again, we see a characteristic closely allied to the tentative nature of knowledge in science. Much of what we derive from research is a function of probabilities. A tremendous amount of the knowledge in the behavioral sciences (e.g., psychology) is a function of probabilities rather than absolute, dogmatic conclusions. How often do you hear something like, "One who is male and smokes two packs of cigarettes a day will have a greater probability of respiratory disease than..." This statement is based on probabilities rather than on certainties. This is what science is all about. It permits man to predict future happenings with a high level of confidence.
>
> And, finally, scientists believe that scientific knowledge should be public. This is an ethic which is sometimes violated by the scientific community but one which is a basic belief nevertheless. Probably the most prevalent reason for arguing for public knowledge is one closely associated with replicability. If knowledge is made public, its "goodness" or veracity can be tested by other scientists under similar conditions.

(2) . . .understands the relationships which exist between science and technology and how these pursuits influence society. Among other things, children should understand that there are striking differences between science and technology. At the same time, the child should understand that science and technology tend to support each other and that the relationship between the two is a close one. This is rather like looking at both sides of the coin, and it is imperative that this be accomplished.

Allied with the above, the writers firmly believe that citizens (young and old alike) must realize the tremendous limitations of science and technology. Far too many people tend to see science and technology as omnipotent or all-powerful although this is totally absurd. This perception tends to permit citizens to foolishly rely on science and technology to solve many of the persistent problems facing man. In reality, science and technology are man-controlled and capable of solving only those problems which are amenable to investigation and solution by technological means. Most of man's problems must be faced squarely by man acting in consort with other human beings in a citizenship capacity and not by relying on either science or technology. It appears cogent to help youngsters perceive that they cannot abdicate their own responsibilities to science and technology.

Further, it is important for human beings to realize that the activities of science and technology are controlled by society. Society has certain perceived needs and these are These demands can be humanistically oriented, politically often translated into demands on science and technology. oriented, or economically oriented, or combinations of these. Of course, a good deal of what science researches is science-oriented - science for its own sake, so to speak - the search for knowledge as a function of man's curiosity. This basic curiosity has led to some of the most startling discoveries ever made. Consider the X-ray, the research leading to the theory of evolution, space exploration, etc., etc.

Closely associated with the above characteristics of science is another that deals with the value of scientific knowledge. Oftentimes what science discovers is seemingly with little merit as far as technology or society is concerned. However, time after time, seemingly valueless knowledge has turned out to be of considerable importance later on. Many, for example, believe that the nation's space program is a waste of money. Another decade or tens of decades may prove that the expenditure of money was very efficient indeed. What breakthroughs are ahead in harnessing the vast amounts of energy that exist throughout the universe? Could the seemingly silly research on solar winds provide man with a basically free transportation energy source down the road? Are the natural resources of the moon and Mars possible resources for man on earth in another twenty years? Can what we have learned about man's physical reactions in space be converted to save lives on earth? On and on . . . The vast backlog of scientific knowledge being gained in a multitude of research studies can have tremendous consequences for man's own survival in the furture.

(3) . . . understands and can apply key concepts of scientific knowledge in his daily life. Knowledge, in part, permits man to acquire new knowledge. This, of course, is done via the process-product cycle with which you are already familiar. Knowledge also helps free man from the chains of superstition. Although there is no complete agreement as to what constitutes this literacy component, it is obvious that certain key concepts are of great importance in a sound general education. A few of these concepts which the writers and others perceive to be important follow for purposes of example.

The idea that things happen in the universe because of cause-and-effect relationships appears critical. The cause-and-effect concept has a close relationship to understanding that the universe is more or less orderly and that happenings can be predicted with high degrees of probability. Naturally, this idea should also have the impact of allaying many of man's superstitions.

Concepts dealing with the relationships between matter and energy also appear critical to literacy. Human beings interact with these relationships each and every day of their lives. What are the relationships? Can matter and energy be universally conserved? Are there exceptions to this conservation? What are the implications of these ideas to human beings as they interact with the environment?

The concept of homeostasis should probably be considered as a key concept in the literacy dimension. Homeostasis can be defined as a state of equilibrium or a tendency toward such a state between different but interdependent elements. On the surface, this appears to be quite an idea - too difficult, perhaps, for children. Not true! A healthy organism is homeostatic. The bits and pieces of that organism are working together successfully - in equilibrium if you will. More importantly for the children, perhaps, is the notion of homeostasis as it involves their environment. Are living communities becoming less and less balanced as a function of man's activities? Or, are they able to sustain homeostasis? Is man in a homeostatic relationship with the biosphere or are there severe threats to this equilibrium? The ecological implications of homeostasis are significant and of importance to every man, woman, and child on the planet Earth.

Concepts concerning both asexual and sexual reproduction seem appropriate for a list of key concepts. All living species must be able to reproduce themselves or become extinct. Further, man is a reproducing organism. That children should understand the basic principles of reproduction seems critically important. Note that the writers are not confusing reproduction with sex education. Sex education is a much broader amalgam of concepts than reproduction *per se*.

The examples stated above represent only a small number of those concepts which are often perceived as important from a literacy perspective. Others might include such things as evolution, work, the organism, population, community, ecosystem, pollution, time-space relationships, relativity, and theory.

(4) . . .understands and can use the science processes associated with basic inquiry or problem-solving strategies. When we speak of science processes we are dealing with those intellectual skills used by the scientist as he goes about the business of doing science. These processes are closely allied with what educators term "critical thinking." And, they probably have application (transfer potential) to all aspects of human activity, which means that the processes of science can be used in problem-solving activities beyond science. However, it may well be that science education can do a great deal to foster critical thinking in the human being and help students maximize their intellectual potential. This may well be the major contribution of science in the elementary school curriculum. Whether or not science contributes to critical thinking ability in students depends entirely on whether these thought processes are taught and therefore, actualized. This is not an easy task but it is possible!

Because an entire chapter in this worktext deals with science process, the writers will only provide a generalized description of these here. Science process includes such intellectual activities as observing, comparing, classifying, inferring, hypothesizing, designing and conducting experiments, predicting, and measuring. Those of you who learned in school that there was such a thing as a "scientific method" will be quick to note that many of these processes were referred to as part of that method. Today, however, most science educators take the position that there are many methods in science and that different scientific activities utilize different sets of processes.

(5) . . . appreciates and can apply the basic attitudes of the scientist. Certain values operate in science and these values are reflected in the more commonly held attitudes of scientists as they engage in research. Some of these values relate directly to the logic behand

empiricism. Others are values held by the individual who is motivated to be involved in science itself. Basic curiosity is one of these and is closely allied to man's longing to know and understand. This attitude is often based on the premise that knowledge has value and that empirical inquiry should be undertaken to obtain that knowledge.

Another value is that associated with the demand for verification. A scientist often rejects knowledge that cannot be supported with hard data. At the very least, the scientist suspends judgment on a finding or theory until data are available which tend to reject said knowledge.

Most scientists have a sincere respect for empirical logic. Here the scientist insists that conclusions drawn from scientific work be based on a logical frame of reference with respect to available data. At the very simplest level, this characteristic is demonstrated by the insistence that an inference drawn from an observation be based on the logic of the situation rather than on intuition. In this way, scientific knowledge differs from dogmatic or intuitive knowledge. And, this is a difference that is critical to all of the activities of science. It is this, perhaps as much a any other single thing, that separates science from less empirical intellectual pursuits. (pp. 9-13)

Tyler (1949) recommends construction of a two-dimensional chart to facilitate the clear and concise expression of such educational goals as instructional objectives. In constructing the chart, the kinds of behaviors to be developed by students are listed along the horizontal dimension. Along the vertical dimension are listed the areas of content to which the behaviors apply. The chart thus graphically portrays a set of behavior and content specifications for which instructional objectives can be written.

In applying this technique to the selection of science curricula aimed at the creation of scientifically literate citizens, science teachers would first need to define the content and the behavioral dimensions of the chart. The content aspects would consist of selected factors from a definition of scientific literacy. Labels on the behavioral dimension might consist of performance levels from the cognitive, affective and/or psychomotor taxonomies. The specific dimensional variables chosen, of course, would depend upon the range of grades and science disciplines for which curriculum materials were to be selected.

Figure 1 presents an example two-dimensional chart for a ninth grade environmental science/education course. The content dimension includes factors from the Hungerford and Tomera (1977) definition of scientific literacy. The behavioral dimension labels are primary levels from the cognitive domain taxonomy (Bloom, 1956) and the psychomotor domain taxonomy (Krathwohl, Bloom and Masia, 1964).

| | BEHAVIORS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cognitive | | | | | | Affective | | |
| **Dimension I:** | | | | | | | | | |
| a) empirical | | X[a] | | | | | | | |
| b) tentative | | X | | | | | | | |
| **Dimension II:** | | | | | | | | | |
| a) controlled by society | | X | X | X | X | X[b] | | | |
| b) limitations of science and technology | | X | X | X | | | | | |
| **Dimension III:** | | | | | | | | | |
| a) cycle | X | X | X | X[cd] | | | | | |
| b) ecosystem | X | X | X | X | | | | | |
| c) energy-matter | X | X | X | X | | | | | |
| d) homeostasis | X | X | X | X | | | | | |
| e) interaction | X | X | X | X | | | | | |
| f) limiting factor | X | X | X | X | | | | | |
| g) population | X | X | X | X | | | | | |
| h) succession | X | X | X | X | | | | | |
| **Dimension IV:** | | | | | | | | | |
| a) controlling | | X | X[e] | | | | | | |
| b) designing studies | | X | X | | | | | | |
| c) hypothesizing | | X | X | | | | | | |
| d) interpreting data | | X | X | | | | | | |
| e) predicting | | X | X | | | | | | |
| f) questioning | | X | X | | | | | | |
| **Dimension V:** | | | | | | | | | |
| a) longing to know and understand | | | | | | | X | X | X[f] |
| b) demand for verification | | | | | | | X | X | X |
| c) suspend judgement | | | | | | | X | X | X |

Figure 1. Two-dimensional chart for an Environmental Science/Education Course.

The Xs on the chart designate content-behavior couples considered by the teachers who constructed it to be educationally significant, and for which at least one instructional objective was chosen to be stated. Superscripts a) through f) on the Xs refer to the following example instructional objectives prepared for the course.

a) The student is able to describe in his/her own words the characteristics of environmental studies which make them empirical.

b) The student is able to indicate the appropriateness/ inappropriateness of the five environmental action methods [persuasion, consumerism, political action, ecomanagement and legal action (Hungerford et al., 1978)] for attacking a given environmental problem.

c) The student is able to identify at least one effect a given human activity may have on the hydrologic cycle.

d) The student is able to identify at least one effect a given human activity may have on the geological materials cycle.

e) The student is able to control confounding variables in environmental studies he/she undertakes.

f) The student believes that knowledge about the environment and man's interaction with it are desirable, and that participation in environmental inquiry to generate this knowledge is a worthy activity.

For each of the other content-behavior couples denoted with Xs in Figure 1, at least one instructional objective was written. In a number of cases more than one component of the content dimension was pertinent to the content-behavior couple (e.g., designations c and d) and so, more than one instructional objective was written by the science teachers.

Following Tyler's (1949) model, the adoption of a definition of a scientifically literate citizen and the use of a two-dimensional chart to derive pertinent instructional objectives comprises the first step for science teachers undertaking curriculum consumer action. The next step involves use of these instructional objectives to screen the learning experiences tacit in science curricula under consideration for adoption.

## Selection of Learning Experiences

Tyler (1949) identifies the problem associated with selecting learning experiences as that ". . .of determining the kind of experiences likely to produce given educational objectives and also the problem of how to set up situations which will evoke or provide within the students the kinds of learning experiences desired" (p. 65). In response, he suggests that instructional objectives be scrutinized to determine characteristics desired in related learning experiences. To expedite such decisions, Tyler tenders five general principles to apply in the selection of learning experiences for an instructional objective: 1) students must have experiences that give them opportunities to practice the kinds of behaviors implied by the objective; 2) learning experiences must be satisfying to students; 3) students are able to attain the behaviors required in the experiences; 4) there are multiple experiences that can and should be used to attain the same objective; and 5) any one learning experience will typically produce several outcomes, including some not desired.

Application of Tyler's (1949) learning experience selection principles to the science curriculum selection process would mean that learning experiences provided for in curricula under consideration for adoption would need to be systematically assessed against the instructional objectives specified for the science course or program. That assessment would need to be completed in terms of each of the five learning experience selection principles Tyler provided. Only in that way could a science textbook adoption committee be assured that a valid and objective comparison had been made of curricula based upon science course or program instructional objectives.

Construction of an assessment sheet which lists science course or program instructional objectives down the page, and reference questions associated with the five learning experience selection principles across the top of the page, would greatly simplify the review process. The reference questions might include those presented in Figure 2.

As a curriculum is reviewed, the reviewer(s) would enter coded ratings, next to the instructional objectives and under each reference question on the chart, that designate the judged adequacy of the learning experiences it lays out. A numerical rating scale might be used. One such scale would be a 0 to 5 scale wherein the 0 stands for a lack of learning experiences on an instructional objective, with the 1 through 5 numerals signifying more positive responses to the reference questions.

Use of an assessment sheet of this type during textbook adoption procedures will greatly increase the probability that the science curriculum materials which are selected contain learning experiences which will elicit the desired behaviors in students, as these are stated in a set of instructional objectives. If that set of instructional objectives was derived from a definition of scientific literacy, then the science instruction which is provided students should take them toward that goal.

| Learning Experience Selection Principle | Reference Question |
|---|---|
| 1. | Do the learning experiences give students an opportunity to practice the behavior implied by the objective? |
| 2. | Will students obtain satisfaction from carrying out learning experiences? |
| 3. | Do the learning experiences involve the kinds of behaviors the students are capable of performing. |
| 4. | Are a number of different learning experiences provided on the objective? |
| 5. | Are the learning experiences likely to produce undesired outcomes? |

Figure 2. Learning Experience Selection Principle Reference Questions.

## SYNOPSIS

The science textbook adoption process is an institution familiar to all experienced science teachers. It is a process typically approached by all involved -- science teachers, administrators, parents, and science textbook publishers -- with honorable intentions. Nonetheless, a tail-first approach is often taken to the task. Science curricula are selected for frivolous or vain reasons, with little or no forethought given to educational purpose, and are frequently established after the fact by the curriculum materials which have been selected. These *de facto* statements may even differ between grade levels and science courses as the science curricula themselves differ. Yet, because the existing science curricula concentrate on communicating scientific knowledge, science is taught in most secondary schools for the purpose of preparing science professionals.

As a result of this haphazard approach to science curriculum design, little more than lip service has been paid to the goal of citizen scientific literacy over the past two decades. That should not have been and need not continue to be the case, however. Through the type of consumer action endorsed in this chapter, science teachers can bring a purposefulness to science instruction which serves the needs of the general populace. Tyler's (1949) curriculum design rationale provides a viable means which science teachers can use, in concert with a definition of scientific literacy, to generate instructional objectives consistent with that goal. Those objectives can then be used as one basis for evaluating the learning experiences in science curricula.

Until science teachers reverse present practices and begin to select curricula based upon the goal of citizen scientific literacy, it is unlikely we will observe a significant move toward that goal. Where citizen scientific literacy is concerned, the decision is ours.

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## BUT.....IT DOESN'T WORK FOR ME

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## INTRODUCTION

"But it doesn't work for me..." At conventions and curriculum presentations we often hear of the new, great curriculum that is designed to solve many of our teaching problems. While observing other teachers we note that they seem to have found that perfect curriculum. On reflection or after a painful trial (in some instances a four-year trial!), we realize that the superb-looking curriculum will not work for us. Daunted, but not down, we continue looking...looking...looking.... Mesmerized as we might be by the excellent presentation of a master teacher and/or author, we are awakened by the cold light of reality. Teaching a new and different course brings home all too often and painfully the difficulty of shifting to a new program that requires more than just a new text, new labs, and new assignments. As teachers we do not face this difficulty alone. Developers of one curriculum project designed for secondary school science noted time after time that the course and materials were suitable for only two percent of the science teaching and learning population. The designers shuddered when a well-known publishing house attempted to sell this curriculum as good for all! Not many schools adopted the program, but, strange as this may sound, the curriculum is still being taught today. For some teachers it is the best possible earth science program.

Why is one teacher's "perfect curriculum" so unpalatable to another? What is it about some curricula that doom them from the start? Why are some programs critical successes yet practical failures? What models from Tyler's work and others can guide us through the morass of program selection to the perfect curriculum? It is hoped that these and other questions will be answered as this chapter unfolds, and we will benefit from insights into the dilemma "But it doesn't work for me...."

## A FEW VIGNETTES OF TEACHING SCIENCE

Why do problems exist in the teaching of science? To examine this question, we will look at four vignettes: Lab All Day Every Day; The Great Design; By the Book; and From the Mouths of Students. While they are exaggerated, each vignette presents its teacher with some of the problems faced by any of us each day. While the vignettes are real, the names of the teachers are fictitious, and any match with someone you know is purely coincidental. However, can you find yourself in each of these?

## Lab All Day Every Day

Mildred Fetisque is sold on the notion of THE way to teach science. Starting on the first day of a new school year, she announces to her students that they are going to learn science the way science is done. Using extensive and expensive special equipment, she has the students carry out experiments each day in each of her five science classes. Acting as a facilitator as well as a manager of equipment, she guides the students through a series of experiences to develop an understanding of the nature of science as scientists. After about three weeks she notices that the students' high enthusiasm has slowly cooled, and some are even asking for...yes... questions to answer at the end of a chapter of readings. Also Mildred, noting her own decreased energy level, feels that she wouldn't mind changing. After experiencing two or three occurrences in which, try as she might, the students don't seem able to conclude any more than the most routine inferences from the excellent experiments she has provided for them, she announces "BUT...IT DOESN'T WORK FOR ME."

## The Great Design

Walter Smedly has also found THE curriculum. In his curriculum the beauty of the structure of science is presented. Through a program of lecture, discussion, reading, and problem solving the students are made aware of the thrill of science models and theory. Although the process begins smoothly, Walter notes that the students do not understand the great design. He must lecture more and enjoy less. Soon he notices that teaching science has lost its zest, and he thinks that perhaps he should join his brother's computer cleaning business.

## By the Book

Alma Curlew has selected THE best selling high school science text in her subject area. The publisher's representative has provided help, and Alma attended a workshop on the use of the materials and text. Following the teacher's guide exactly, her students get through the book each year in spite of the fact that she would like to spend more time on other topics of current interest. She also notes that some students have trouble with the reasoning concepts in the test. "They just want the answers," she mumbles of herself on the way to the teachers' lounge, worn out on a Friday afternoon.

## From the Mouths of Students

Oswald Minicule, our fourth teacher, uses THE curriculum built on the students' interests. As the students start the year, they decide what in science interests them most. From this base student teams, based on similar interests for friendship, pursue subjects, from rocketry to parquetry, from recombinent DNA to destructive PBB. Oswald uses his best teaching skills and works to make the principles and concepts of science emerge from the students' thinking. It seems to be going well, but lurking at the back of his mind are the ever-present SAT tests.

Certainly each vignette is based on a fictitious character, but we may see ourselves and/or fellow teachers in each vignette. Worse, we may see a little of ourselves in every one. For some THE curriculum works perfectly, but for many others there is no "perfect curriculum." Perhaps there should not be a need for the perfect curriculum, and perhaps our search is an endless quest. But why does Oswald worry about the SAT's, and why does another teacher, using the same type of curriculum, not worry, having students that do very well on all the college entrance exams? To place the problem in perspective, let's examine two models: one model proposed by Ralph Tyler (1949), followed by a model derived from current research on teaching, learning, and problem solving styles.

Ralph Tyler published his thin volume more than three decades ago, but Basic Principles in Curriculum and Instruction continues to be a valid model for curriculum design. Delineated earlier in this volume, the principles are useful for preparing curricula. Less well known are Tyler's "defects indigenous to any system of education." If you read between the lines of the four vignettes, you may have already detected the "defects" as outlined by Tyler (1949). They are:

1. Students frequently memorize by rote and thus do not acquire any real understanding. Frequently they are not able to apply the ideas that they do remember.

2. Many students show a rapid rate of forgetting.

3. Students often lack a means of adequately organizing what they learn.

4. There is always a degree of vagueness and inaccuracy in what students do recall.

5. Students show limited familiarity with sources of accurate and recent information.

The above defects may look familiar; they can be matched with the aforementioned vignettes. Did you match defect #3 with Mildred Fetisque? Did you compare #5 with Walter Smedly? Does defect #4 parallel with Alma Curlew? Do defects #1 and #2 constitute matches with Oswald Minicule? (Other matches are also possible...so much for closed-ended responses!) Remembering that these defects were enumerated more than 30 years ago lends a touch of hopelessness to the notion that educational systems have made any great progress. Yet research in education has made some excellent progress lately, and results of studies in meta-memory, Piagetian psychology, instructional systems design, and problem solving are just now being translated into practice. Researchers such as Mary Budd Rowe and Rita Peterson are working hard to translate research into practice, and as you read the chapters in this volume, you may note several translations by the authors. This chapter is no exception.

The research that illustrates Tyler's "defects" and explains why curricula do not work equally well for all persons is the research loosely called "styles." Three types of style research are currently prevalent. Most elaborate is the work on learning styles. Less well developed is the study of teaching styles. Just evolving now is work on problem-solving styles. Problem-solving style research is an especially promising area. Results may lead to insights in teaching and learning styles that can not only provide information on Tyler's "indigeneous defects" but also help us understand why "...it doesn't work for me...."

## PROBLEM-SOLVING STYLES

Work relating problem solving, learning, and teaching styles was first reported by David A. Kolb and his colleagues, Irwin Rubin and John McIntyre (1979). This work came from Kolb's earlier work (1976) on learning styles. Gathering data from thousands of adults in varying occupations, Kolb found that people could be categorized into four styles representing two dimensions (see Fig. 1). Across one dimension was a pattern in learning style of active to reflective; across a different dimension was a pattern from concrete to abstract. These dimensions sound familiar to those of us acquainted with Piagetian psychology. Concrete operations and formal or abstract operations are two of Piaget's developmental states. Further, we are all familiar with students who learn actively or reflectively or, as Kolb puts it, the "doers and the watchers."

Using the very simple and straight forward "Learning Style Inventory," which takes about 5 to 10 minutes to complete, Kolb (1976) found striking differences in the learning styles of adults in different occupations. He also found marked differences related to the basic personalities of the people tested. Striking as these differences may be, they fit remarkably well into reasonable theories of personality and occupation selection. For example, in a large sample of MIT seniors, business majors were highly active and concrete, whereas physics, chemistry, and mathematics majors were highly abstract and somewhat reflective. Political science and history majors, on the other hand, were highly reflective and concrete. Engineering students were active and abstract. In studies identifying elementary and secondary teachers, colleagues of Kolb found that elementary teachers were highly concrete, and secondary school teachers were more abstract; both were equally active (see Fig. 2).

Kolb, Rubin, and McIntyre extended these learning style investigations into the field of problem solving. In their book, Organizational Pyschology: An Experimental Approach (1979), the authors noted problem-solving steps that they identified with locations on the learning style chart. Starting from the 3 o'clock position and proceeding clockwise, as shown in Fig. 3, they defined a series of two steps in each quadrant that could be thought of as steps of a problem-solving process. These steps are:

1) Select a problem
2) Consider alternative solutions
3) Evaluate the consequence of solutions
4) Select a solution
5) Execute a solution

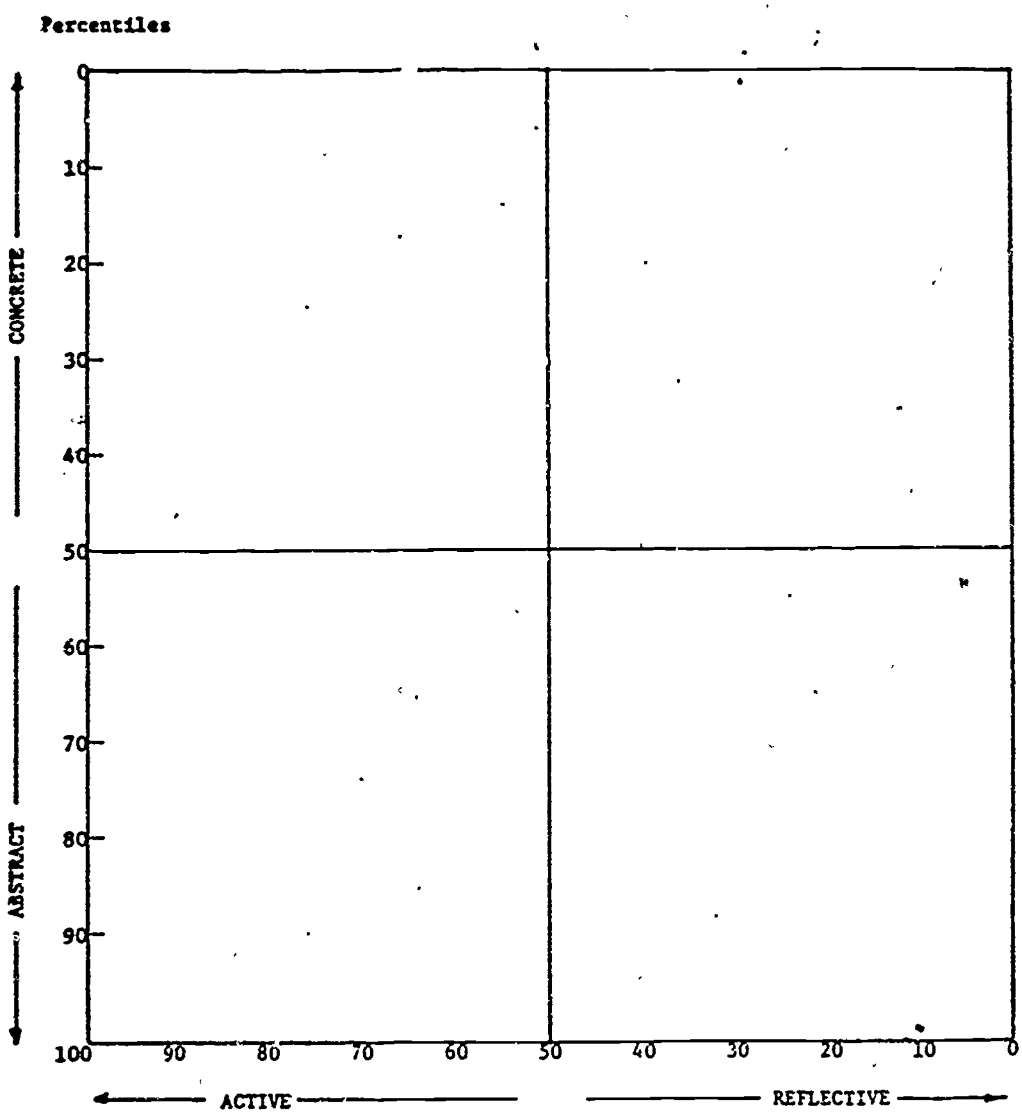


Figure 1

LEARNING STYLE TYPE GRID

(Adapted from Kolb, 1976)

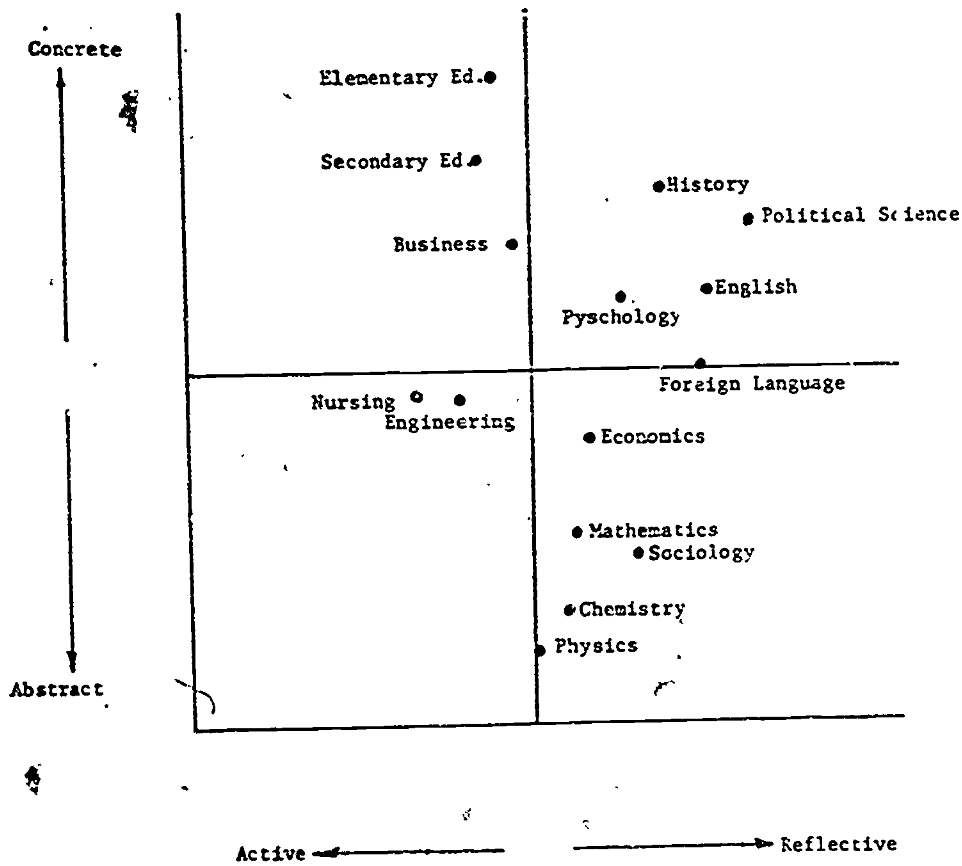
Concrete
Abstract
Elementary Ed.
Secondary Ed
Business
History
Political Science
English
Pyschology
Foreign Language
Nursing
Engineering
Economics
Mathematics
Sociology
Chemistry
Physics
Active
Reflective

Figure 2

6) Chose a model or goal
7) Compare it with reality
8) Identify differences (problems).

David Keller, of the Akron Public Schools, and I noted that these steps were similiar to steps in a scientific method (neither of us believe there is THE scientific method). We generated another similar series of steps that might be more recognizable to science teachers. They correspond to the above steps and are listed below:

1) Select a problem related to a model
2) Develop hypotheses
3) Evaluate to find the best hypothesis
4) Select and experiment to test the hypothesis
5) Carry out the experiment
6) Draw conclusions
7) Compare conclusions with the model
8) Identify new problems and/or models

These steps are very similar to many scientific methods or problem-solving models such as one reported by Dorothy Cox (1980). Armed with this new information that could relate to science teaching, David Keller and I wondered if science teachers had a particular problem-solving style. We tested 76 teachers who were working in a demonstration project for gifted students in the Akron Public Schools. Using Kolb's Learning Style Inventory, we first checked to see if we could identify the same dimensions from our data as Kolb had from his. We were quite pleased and not a little bit surprised to find that our results compared very well with those of Kolb. We could independently produce the same dimensions of "concrete-abstract and active-reflective" that Kolb had found in his original data. We did this through a complex statistical process known as principal component analysis. Not only could we produce the dimensions, but there appeared to be no single learning style or problem-solving style that clearly dominated our population of teachers (see Fig. 4).

Thus, it is no small wonder that any single curriculum will not be appropriate for all teachers, and perhaps this is the source of the expression, "But it doesn't work for me." It appears from Fig. 4 that these 76 teachers fit, and each may be comfortable with, varying parts of a scientific method. Some might emphasize more the hypothesis portion of science, others the experimentation segment, still others the application part, and some the model generation portion. For fun, we could place Mildred Fetisque, Walter Smedly, Alma Curlew, and Oswald Minicule on the chart, not by their learning style, but by their teaching style. Kolb's research on teaching styles indicates that there is a close match between learning and teaching styles (1976).

Are our teaching and learning styles so closely related to our personalities and occupations that they are set and immutable? The research on this question is not clear, so David Keller and I tried an experiment. We attempted to find out if the problem-solving style of teachers could be modified by the kind of activity the teachers were involved in during a workshop. We generated three simple experimental activities that involved different parts of a problem-solving or scientific method process. Each of

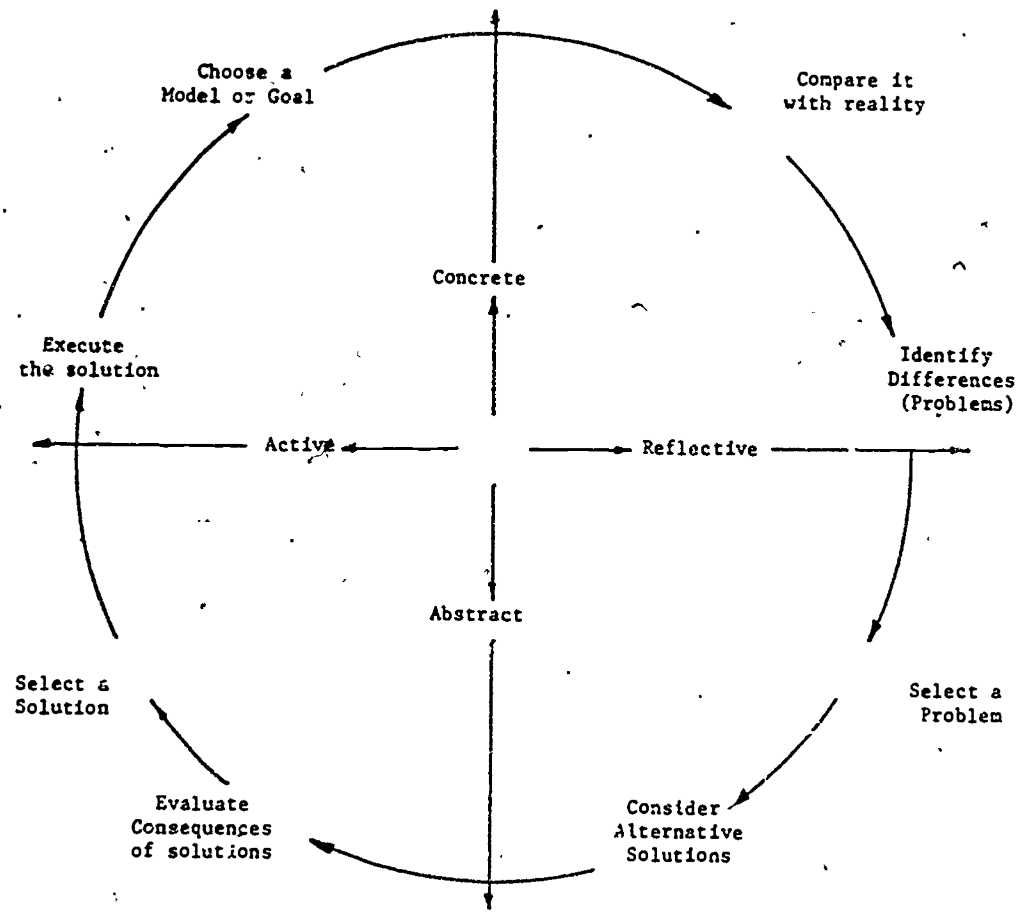


Figure 3

A COMPARISON OF THE LEARNING MODEL AND THE PROBLEM-SOLVING PROCESS

(Adapted from Kolb, Rubin and McIntyre)

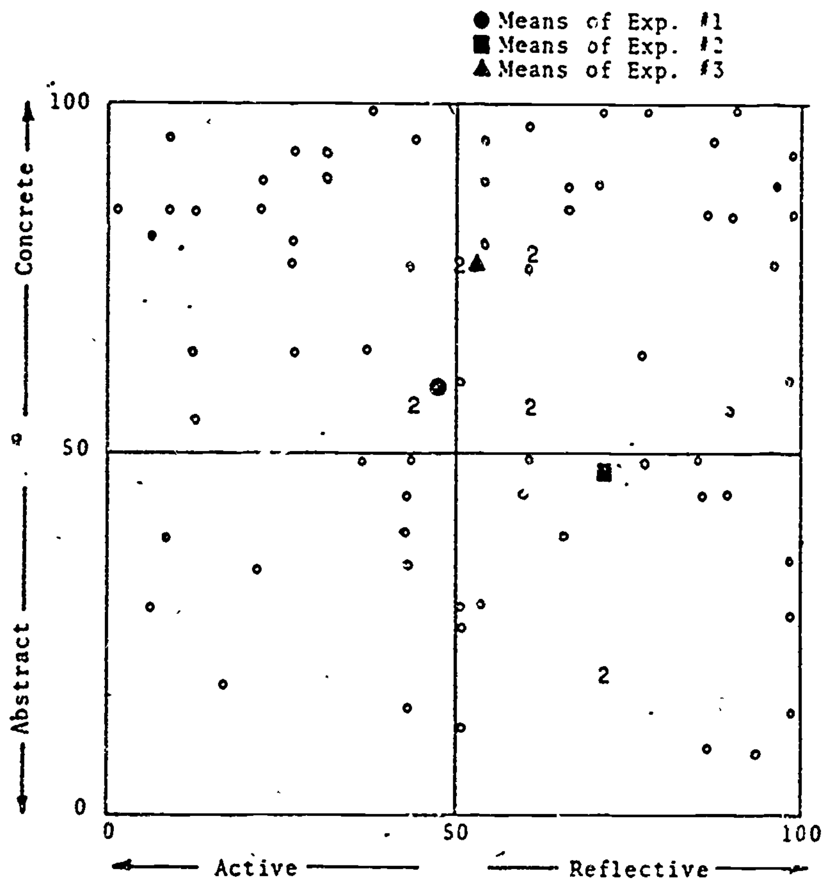
Means of Exp. #1
Means of Exp. #2
Means of Exp. #3
100
50
0
Concrete
Abstract
0
50
100
Active
Reflective
2
2
2
2
2
2

Figure 4

these experiments, we hoped, would require the use of a problem-solving segment found more in one quadrant of the model than in another. We could then determine if the teachers modified their problem-solving style by shifting toward a particular quadrant depending upon the kind of experiment. Our first experiment was designed to be both in the active and abstract quadrant. In this experiment, teachers had to support a book 5cm above the table using only a file card. We thought that this activity would encourage teachers to reason abstractly and then actively build a structure with the file card to support the book. Experiment number two was designed to be in the reflective and more abstract quadrant. In this activity, teachers, working in groups, had to generate a food web, remove one or two links from that web and infer changes that would occur in the food web. Next, they were to compare the changes with a similar activity done with an energy web. Our third experiment was designed to be in the active and concrete quadrant. It involved the use of a simple drop reaction timer to measure reaction time; teachers were to modify their reaction time through a series of experiments. We hoped that the data from the Learning Style Inventory, administered just after each activity and reflecting on the problem solving during the activity, would show shifts toward the quadrants emphasized in the particular experiment. The results of our work with these 76 teachers exceeded our expectations. As shown in Fig. 4, in each activity the means of the group fell in the appropriate quadrant. Further, there were strong significant differences among all three means, well beyond the traditional expected levels of statistical significance. Again, the teachers covered the entire spectrum of quadrants, and while the overall mean of each group did shift in the expected direction, strong individual differences were still apparent.

Our conclusion is that while teachers maintain a strong individual problem-solving style, that style can be modified, depending upon the particular activity involved. We hope to do further research to determine if teaching styles also change in given activities. My own work in the late 60's and early 70's shows marked evidence of the relation between teaching behavior and teaching style perception, and that differing activities encourage wider ranges of teaching styles (Berger, 1977).

What has this to do with Tyler's indigenous defects? First, some inferences. Our teachers exhibited wide ranges of problem-solving styles. Students must also exhibit these wide ranges. Teachers' problem-solving styles can be modified by the kind of activity involved. Such shifts, because they evolve from using different kinds of activities, may add to teachers' repertoires of activities and enjoyment in teaching science. In discussions with our teachers, they unanimously indicated their appreciation for the wide variety of styles of activities rather than a focus on a single style of activity that is often emphasized in a science workshop. Let us use these inferences to resolve Tyler's "defects." First, we need to understand that both teachers and students have unique, personal problem-solving styles. Second, we can encourage a shift in problem-solving style, but we must realize that such a shift may be small, particularly if students are not yet full in an abstract developmental stage. Third, we may need to spend more time as teachers developing and teaching activitie that emphasize a wide variety of problem solving or scientific method steps. It may be easy for us to emphasize activity or memorization, and this may be reinforced by the prevalent learning styles of our students. Yet it is most important that we provide a wide variety of experiences for ourselves and our students. If we do, we can draw implications for teaching.

## IMPLICATIONS FOR TEACHING

What are the implications of style research for teaching? Perhaps you have made some obvious conclusions yourself. In any teaching situation, the same problem-solving style cannot be expected from all students or all teachers. In any cycle of teaching and learning that involves a scientific method, the model in the research above suggests that many different problem-solving styles are needed. Thus, while a teacher may find more comfort teaching in the problem-solving style that most closely matches his or her own personal style, a more appropriate problem-solving activity may be needed. Equally clear is the notion that, while possibly uncomfortable, the situation or activity can encourage change in teacher behavior and certainly must in student behavior! By accepting a most comfortable problem-solving style in teaching, we may be following a routine that does not allow us as teachers to add to our repertoire of fine teaching techniques. Some of the most exciting times in teaching are those where we try new teaching techniques, fully admitting to the students that such techniques may not work. It is not critical that we are able to teach equally in all four problem-solving quadrants. However, it is important that we have within our teaching skills the ability to present situations which can challenge students in all four quadrants.

Looking back at the four vignettes, it may be clear that too much emphasis was placed on one aspect of problem solving through teaching. Perhaps Mildred Fetisque focuses far too much on the concrete active quadrant, and the students are reflecting their needs to have activities in reflective as well as abstract quadrants. Spending a great portion of teaching time emphazising one quadrant may not only give a stilted view of what science is, but it also may influence a feeling by some students that science is not for them, as their own problem-solving styles do not match the particular quadrant being emphasized.

Walter Smedly's Great Design may over-emphasize the reflective abstract nature that certainly is a strong characteristic of science. But it is not the only characteristic of science. For Walter and his students, a mix of wider teaching styles may be more interesting, not only for students but also for Walter. The work of Crowfoot and his colleagues at the University of Michigan (1979) indicates that, contrary to popular opinion that attitude influences behavior, behavior influences attitude. While our Mr. Smedly may not particularly enjoy a concrete active learning situation, the practice and use of such teaching with the concomitant observation of its effect on the students can go a long way toward building this kind of activity into Walter's teaching styles. It is easy to describe such activities as a "bag of tricks." Perhaps change starts out that way, but as we observe more and more honest changes in students it becomes less trick and more art. Science and magic -- something necessary for all science teaching.

Almost as important as the ability to work in particular quadrants of problem-solving styles is the grouping of students so they can work in all quadrants. Controversy about missing or matching has raged in research on teaching and learning styles. A report entitled Practical Applications of

Research by Phi Delta Kappa (Gephart et al., 1980) indicates that mixing and matching is situation dependent. Matching students together by their particular problem-solving styles may make for pleasant company and particular success on that team's activity, but may not be particularly helpful in a total problem-solving situation that requires all four quadrants for successful activity completion. Oswald Minicule may be faced with the notion of student interest overriding student learning, and he may wish to regroup the students on the basis of missing their problem-solving styles.

## THE CURRICULUM FOR WHOM?

Ask not for whom the curriculum tolls, it tolls for thee.

More and more science teachers are being asked to modify their curricula to include groups of students that have not been integrated into science curriculum. Public law 94-142 has legislated that students with special needs shall be placed in the least restrictive environment. For many physically and/or mentally handicapped students, and for their teachers, this means mainstreaming. Career education for all students has demanded science teaching that prepares students who, a few years ago, would have seen their last class in science in seventh grade. It is hard to pick up a current news magazine and not be struck by the tremendous societal implications of science. Noting that our students are future voters forces us to consider issues in science education that shake the once popular notion that science is a value-free discipline. Pressure groups are concerned that science teaching has become too dogmatic and want to include theories of creation as well as theories of evolution. Small wonder that we as science teachers feel pressured, over burdened, and unappreciated. Even worse, public reaction to technological problems and the lack of national commitment to science and science teaching has removed the once unique position that we had in the minds of students and parents.

Certainly we still must prepare students in the best way possible. We should not feel ashamed to have students do the memorizations and mathematical problem solving that prepares them for college science. We have an obligation to do as good a job for those students as we do for any student with special needs. In spite of all of this and, yes, because of all of this, the science curriculum must be for us. It is far too easy to believe that because we must meet the needs of different students, teach what we believe to be nonscience dogma, and cope with all other problems in science teaching, we can no longer enjoy teacing our discipline. Yet we must enjoy teaching, we must be challenged by our teaching in order to survive as teachers. In short, teaching must be fun for us!

We have new tools to help with all students. Such tools can widen our breadth of learning styles. New work on scientific literacy by Karplus et al. (1977) indicates that we can use the developmental psychology of Jean Piaget and self regulation that students inherently use to assist in the development of scientific reasoning and literacy. New technology, as exemplified by microcomputers, can help provide solid learning in an exciting new framework.

Far from replacing us in our teaching positions, such new technological devices and new techniques for teaching scientific reasoning can help us to enjoy science teaching more by providing time for student reflection or time for student experimentation. We can use such time to share our enthusiasm and gain a breather to maintain our composure.

Thus, it is important that we have in any curriculum multiple activities of differing kinds, that we allow time for reflection, that we encourage our students to work with others who have different abilities and problem-solving styles. To make science fun for teachers we must try nonroutine activities. Certainly our science classes should work, but they should be as exciting for us as we would hope they would be for the students. Introducing nonroutine activities with the full knowledge that they may not be successful can maintain the excitement of science.

It is also important that we use our students as experts in learning styles and utilize their talents as members of a scientific team. By having students act as experts, particularly in those discussions of science and society, we can more completely gain their respect, and we can respect our students even more. Tyler's reflections in the 1950's did not include a view that demanded students to review current events and gain accurate information. Students need practice in drawing conclusions and making societal inferences as much as they need practice in measuring the volume of liquid in a pipet or in drawing graphs. Certainly modern technological controversies on news programs and the use of microcomputer simulations can encourage students to draw conclusions and test models in a solid learning environment.

Using all of these techniques, we can solve the problems outlined by Tyler. In addition, such techniques can allow science to be fun for us as teachers. With such activities, with such a balance, with such classroom organization, we will be able to say "Yes... it works for me!"

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# HOW TO MAKE IT FUN FOR KIDS

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## INTRODUCTION

"Boring!"
"Exciting class today!"
"Deadly!"
"A real turn-on!"
"Why do we have to learn this stuff?"
"Same thing every day!"
"I love science!"
"A waste of time!"
"I'm doing really bad -- I hate it!"
"Great course!"

All of us hear these comments at one time or another in our professional careers. Which do you hear the most in your teaching? How successful are you in decreasing the more negative and increasing the more positive comments heard in your classrooms?

As science teachers, almost all of us were required to successfully complete courses in educational psychology, adolescent psychology, and curriculum and instruction (emphasizing lesson planning, implementation, and evaluation) in order to be certified. We know that motivation is of primary importance in the learning process. During our professional careers (and as students ourselves) we have been exposed to a variety of techniques that work positively or negatively in increasing student motivation. Yet ther s little evidence that we are applying theory to classroom practice -- that we are "turning students on" to science.

In his 1949 publication, Tyler identified four fundamental questions that he felt must be addressed in developing any curriculum and instructional plan:

1) What educational purposes should the school seek to attain?

2) How can learning experiences be selected which are likely to be useful in attaining these objectives?

3) How can learning experiences be organized for effective instruction?

4) How can the effectiveness of learning experiences be evaluated? (p. v-vi).

In developing a rationale to analyze each of these questions, his concern for the interests and needs of students was evident. This chapter will focus on the nature and problems of classroom motivation within the context of the above four questions.

## WHAT IS MOTIVATION?

Understanding motivation provides both a conceptual dilemma and a measurement problem. The term is used broadly in the literature to encompass all of the affective components of personality and environment that influence effort as opposed to ability (Keller et al., 1978).

For the purposes in this chapter, motivation to learn in school is defined as "that which gives direction and intensity to student's behavior in a school situation" (Frymier, 1974). Direction implies selection from possible variations in purposes or goals; intensity implies possible variation in degree of effort (movement toward a goal) put forth to attain the goal (Frymier, 1974). In defining motivation within the context of expectancy-value theory, Keller and his colleagues (1978) suggest that effort is the result of two factors, the motive or need toward which behavior is directed and the expectancy for success. According to this theory, the "greater the likelihood that a person perceives success to be possible, the stronger the effort that is likely to be exerted" (Keller et al., 1978 p. 2). Thus, motivation can be viewed as the combined result of the personal value attached to the attainment of a given goal, the effort exerted toward the accomplishment of the goal, and the perceived liklihood of achieving it (Keller et al, 1978).

## WHAT DOES THE LITERATURE ON MOTIVATION SAY TO THE TEACHER?

The literature on motivation reflects the diverse nature of the topic. Frymier (1974) and Wlodkowski (1978) have demonstrated their ability to communicate and apply motivational research to the classroom teacher. The following illustrate some of the implications of this research for classroom practice.

### Differences Between Motivated and Less-Motivated Students

1. Motivated students tend to have a more positive self-concept than less-motivated students (Frymier, 1974). Wlodkowski (1978) suggests that some students may have neither a negative attitude toward us or the subject matter, but they may have a poor attitude toward themselves. According to Rogers (1969), the maintenance and the enhancement of the perceived self provide the motivation for all behavior. Combs and Rogers describes motivation as "an insatiable need for the maintenance and enhancement of the self; not the physical self - but the phenomenal self of which the individual is aware, his self-concept" (Wlodowski, 1978, p. 48). Students cannot seek out and search for unknown data if they lack a positive self concept. They must believe in their capacities to cope with unknown situations and phenomena (Frymier, 1974).

2. Motivated students tend to be "more tolerant of ambiguity, more open to experience, and are better able to assimilate the new and the novel and the unknown inside their central nervous system than less-motivated students." Motivated students, more readily suspend judgement, are attracted to the unfamiliar or unclear, and prejudge less frequently (Frymier, 1974, p. 9). The above-mentioned characteristics of motivated students have implications for Tyler's concerns for the goals of science instruction as well as for the type of classroom environment we provide. Many teachers appear to feel that they have little control or ability to alter their students' self-concepts. Some perhaps feel that concern for student self-concept is not part of their job. Rather than utilizing motivation primarily as a means to enhance student learning of science content, these traits strongly suggest that motivation can effect more important outcomes in students -- the development of increased positive self-concepts as well as the development of some of the scientific attitudes considered by science educators as basic goals of science instruction.

3. Students from advantaged backgrounds tend to be more positively motivated than are students from disadvantaged backgrounds (Frymier, 1974). While motivation appears related to social class, factors causing this difference have not been clearly delineated.

4. Students in "gifted" classes appear to be more highly motivated than are students in "average" classes (Steele, House, and Kerins, 1971). This finding raises interesting questions concerning the source(s) of motivation for the "gifted" students and teachers of "average" students? How might these differences affect student motivation? Do teachers interact differently with "gifted" students? How does prior knowledge of student characteristics affect teacher interaction with students? How does the home environment affect student motivation in school?

## Expectancy for Success

Tyler (1949) suggested that the learning experiences selected by the teacher should be within the range of possible attainment by the student. One important component in the definition of motivation is the expectancy for success. When we give students a task that they do no expect to perform successfully, they are likely to protect their "psychological well being" by remaining withdrawn and unenthusiastic. Often this behavior is based on a realistic view derived from previous experience and self-awareness. We frequently interpret this as apathy or rebellious behavior. In reality, it is often self-protection (Wlodkowski, 1978).

Wlodkowski is describing a concept psychologists call locus of control. According to Keller et al. (1978), locus of control refers to "a person's expectancy regarding the controlling influences on personal successes and failures" (p. 22) Keller and his co-workers distinguish between an internally oriented person (one who tends to assume that good grades, etc. are more likely to result from personal effort and initiative), and an externally oriented person (one who tends to believe that consequences are largely a matter of circumstances or luck). From data compiled by the Coleman Report of American High Schools, locus of control was found to be the single best predictor of achievement for non-whites (Simpson, 1978). In pursuing a similar line of research, Rowe (1974b) distinguishes between "bowlers" and "crap shooters" in dilineating the variable she calls fate control. "Bowlers" correspond to the "internally oriented" persons above in that they belive they have some degree of control over future situations. "Crap shooters" (externally oriented persons), however, believe that planning ahead is fruitless, as the future is controlled by chance or lies in the hands of others. Rowe suggests that "bowlers" perceive that problems do have solutions and are more active in collecting data and pursuing potential solutions to problems than are "crap shooters."

If we provide students tasks that they want to do and honestly expect to perform successfully, motivation will not be a problem. However, motivational problems will occur when students do not perceive reasonable success. By carefully managing the learning environment, students can perhaps learn to attribute failure to a lack of effort rather than to a lack of ability or external causes (Wlodkowski, 1978).

Harry Wong (former science teacher and author) has, for many years, been an enthusiastic spokesman for increasing student motivation by improving student self-concept and the expectancy for success (Wong, et al., 1978). Part of the success of programs developed by Wong and others for low-ability students is based on high student motivation created, in part, by a high expectancy of success. Similar student behavior was not always observed for earlier NSF curricular efforts.

## Intrinsic and Extrinsic Motivation

One issue that has long faced science teachers is the relative emphasis we place on extrinsic and intrinsic motivation. Extrinsic motivation emphasizes that value a student places on the ends (good grades, teacher praise, parental privileges) of an action. Intrinsic motivation refers to the value or pleasure (internal rewards) associated with a particular activity. The "doing" of the behavior is considered to be the main reason for performing the behavior (Simpson, 1978; Wlodkowski, 1978).

For most of us, our bags of "motivational tricks" are heavily extrinsic in nature. The literature does not support this emphasis. Simpson (1978) states that most psychologists "believe it is important for teachers to help students make a transition from external to internal sources of rewards." Rowe (1974 a, b), in pursuing research related to wait-time, has observed benefits from shifts from external to internal motivation. When science teachers increase their wait-time after asking questions, students tend to demonstrate a number of desirable responses more frequently (Rowe, 1974a). Students also appear to become less dependent on teacher praise. One interpretation of Rowe's data is that by reducing teacher (extrinsic) rewards, students become more intrinsically motivated by pursuing their own interests (Rowe, 1974 a, b). Simpson (1978) suggests that student motivation may be shifted from extrinsic to intrinsic by teachers who are able to demonstrate the ability to control reinforcement.

Staw (1976), in his review of research on intrinsic and extrinsic motivation concluded that:

> there is no doubt that grades, gold stars and other such incentives can alter the direction and vigor of specific 'in

> school' behaviors. But because of their effect on intrinsic motivation, extrinsic rewards may also weaken a student's general interest in learning tasks and decrease voluntary learning behavior that extends beyond the school setting. In essence, then, the extrinsic forces that work so well at motivating and controlling specific task behaviors may actually cause the extinction of these same behaviors within situations devoid of external reinforcers. (Wlodkowsky, 1978, p. 155).

Therefore, to foster intrinsic motivation, the use of extrinsic rewards must be carefully monitored (Wlodkowski, 1978). An important implication is that external rewards should be considered only when the learning activity has inadequate internal incentives. How can learning experiences be organized for effective instruction? The above discussion implies that by fostering intrinsic motivation, positive self concept, and the expectancy for success, more effective instruction will result. This is consistent with Tyler's discussion of this topic more than three decades ago.

It has been strongly suggested that through the proper use of motivation, desired student behaviors can be produced. The following sections identify and briefly describe some of the many sources of classroom motivation for the science teacher.

## CURRICULUM INFLUENCES ON MOTIVATION

In another chapter of this volume, Berger speaks of the search for the new, great curriculum designed to solve many of our teaching problems. Publishers tell us that if we use their science program, our students will be "turned on to the joys of science." Yet, too often this does not occur. What reasons can we give for the continued search by science teachers for a program that will motivate their students?

There appears to be a paradox in the findings of the Project Synthesis group reported by Professor Yager (in Part I of this Yearbook). On the one hand, the primary goal of most science teachers appears to be teaching "fundamental knowledge," relying almost exclusively on the textbook. On the other hand, Yager reports that the emphasis of the most widely used science textbooks relates to the development of basic knowledge for academic preparation. It would appear that the goals of these texts are consistent with the classroom goals of science teachers and, therefore, a match between teacher goals and texts should exist. However, are these goals consistent with the goals of high school students? Do these goals offer sufficient direction and intensity to student behavior (motivation)? Could this factor be instrumental in <u>our</u> lack of enthusiasm for text programs we implement?

Yager states that the Project Synthesis group also concluded that in widely used science texts, "goals related to personal use of science in everyday life, to scientific literacy for societal decision-making, and to career planning and decision-making are largely ignored." His illustration of a text presentation of "insects" typifies the lack of any concerted effort on the part of publishers to related insects with either students or society. Over the past decade, Hurd (1970, 1971, 1975) has called on the science education community to integrate issues involving societal decision-making into science curricula. It seems that neither publishers nor teachers have seriously responded.

It appears appropriate to conclude that if a particular topic is not in the text, it will not be taught. If we want to include social issues that are national, regional, or local in scope, we are left to our own resources--we must scrounge. In Louisiana, for example, there exists a host of environmental issues related to air and water quality, solid waste storage, nuclear power, hurricane barrier protection, and various social issues; e.g. sex education, evolution-creationism. To supplement our texts, we must identify local resource people and work closely with the school librarian in compiling reference lists, folders of materials, audio-visual materials, etc. In short, we must develop our <u>own</u> curricula. The product should match more closely the needs and interests of our students--perhaps a giant step in increasing their motivation. What educational purposes should the school seek to attain? Part of the answer to this question raised by Tyler depends upon classroom teachers' attitudes toward science and their students.

Just as the teacher is the key to instructional design and implementation, so is the teacher the key to the selection of appropriate goals and content that will motivate students. So far, there is little evidence that we have assumed this responsibility.

## INSTRUCTIONAL "TACTICS"

### <u>Variety of Modes</u>

We often tend to utilize a limited number of instructional modes in our teaching. Teacher variables, such as background, experience, and personality, account, to some degree, for our mode selection. Lack of mastery of laboratory skills and techniques, for example, could be hypothesized to discourage many teachers from performing certain laboratory activities in their program, thereby limiting one potentially important source of motivation.

In addition, our educational philosophy, as reflected by our classroom goals, is also an important determinant of mode selection. For example, Mildred Fetisque's (Berger's vignette--Lab All Day Every Day) classroom goals dictate the laboratory as the primary mode of instruction. We might infer that, in this situation, student apathy is due, not to the laboratory activities themselves, but to their overuse in her classroom.

Likewise, a biology teacher whose goals emphasize the development of basic knowledge would probably utilize fewer modes in teaching a "unit" on insects than would a teacher whose goals included societal issues and experiences of the students. In such a society-oriented unit on insects, a number of possible modes can be identified, e.g., lecture, laboratory, audio-visual materials, community resource individuals, field trips, debate of issues, role-playing, and simulation games. It appears that if we are willing to pursue a broader range of goals, it would be much easier to utilize a wider variety of modes. If all other variables could be controlled, we could predict that students receiving such variety would be more highly motivated.

Novelty

A closely-related "tactic" involves the use of novel situations. Knowingly providing false data, puzzling situations, and being unpredictable in your classroom behavior will tend to keep your students guessing and on their toes. Most psychologists (and school principals) would not recommend using this behavior consistently. However, when combined with other modes and teaching styles, it can be hypothesized to increase student motivation. Students want something new in what we do and say. The "surest death of a stimulating teacher is when her or his students can smugly predict her or his classroom behavior?" Wlodkowski (1978). Jearl Walker, physics instructor, Cleveland State University and author of The Flying Circus of Physics (1975) in his quest to increase student attitudes toward the physical sciences, utilizes a wide variety of exciting (and somethimes bizarre) activities to demonstrate selected physics principles. The popularity of his courses and presentations (he is a frequent NSTA presenter) suggests the value of this "tactic" in motivation.

Disequilibrium

One of the most powerful motivational tactics is that of providing students with an encounter that they do not entirely understand--that cannot be immediately assimilated to previous ways of thinking. This contradiction or discrepancy raises a question, creates a state of "disequilibrium," and stimulates students to attempt to resolve the contradiction (Lawson and Lawson, 1979; Berlyne; 1965) suggests that conceptual conflict arising from the use of novelty, surprise, ambiguity, and uncertainty can arouse curiosity in students. Suchman (1966) states that the introduction of a puzzling (discrepant) event provides intrinsic motivation for learning a concept.

The word "tension" is used by Wlodkowski (1978) to describe a state of disequilibrium. Bigge (1976) suggests that when student perplexity is just short of frustration, motivation is at its best. Frymier (1974) and Shymansky (1978) state that a certain amount of anxiety appears to be helpful in "luring" the student into the task. However, we must be careful that the problem is not so complex, ambiguous, or dissonant that the student is overwhelmed and unable to proceed (Frymier, 1974; Lawson and Lawson, 1979). It is necessary to provide the proper match between the task and student ability, knowledge, and personality (Vidler and Lawlor, 1976).

Students with more positive self concepts are more capable of perceiving and coping with greater dissonance than are students possessing less positive self concepts (Frymier, 1974). It could be hypothesized that repeated exposure to discrepancies would create in students an increased tolerance for ambiguity. Thus, we can again see the importance of developing positive self concepts in our students.

Just as texts utilize few instances of societal decision making, the use of puzzling situations, discrepant events, etc. are indeed rare. What this means is that we must modify our instructional sequence to include their use whenever possible. That water expands when it freezes is discrepant to students only if we lead them (down the path) to infer (from previous examples) that substances expand when heated and contract when cooled. Realizing the unique property of water as a potential discrepant event, we must carefully place it into the proper context to ensure maximum motivation.

Involvement Through the Laboratory

The laboratory has been advocated as a primary instructional mode of post-Sputnik science instruction. But how has the science laboratory affected student motivation? A recent review of the role of the laboratory in science instruction (Bates, 1978) revealed positive, but not overwhelming support for the use of the laboratory as a motivational "tactic." Ramsey and Howe (1969) reviewed the effects of "traditional" high school science programs versus their "alphabet curricula" counterparts (PSSC, HPP, BSCS, CHEM Study, and ESCP). In terms of attitude, the evidence strongly suggests that an "inductive, problem-solving, and laboratory-centered approach can be expected to produce signficant positive changes in student attitudes" (p. 66). However, after analyzing studies that closely examined laboratories found in selected alphabet programs, Lunetta and Tamir (1979) concluded that students still perform as "technicians," following explicit instructions and concentrating on the development of lower level skills. They further concluded that most laboratory experiences are of deductive nature, that is, they follow the test introduction of concepts. Hurd and his co-workers (1980), in analyzing the Project Synthesis data, concluded that "the trend is away from laboratory work of any sort in the teaching of high school biology" (p. 403). They found that most laboratory activities were more "rituals than independent inquiry: the problem was given, the procedure programmed, and the result predetermined because there was a 'right' answer" (p. 402). Hurd et al. (1980), as well as Ramsey and Howe (1969), strongly suggest that teacher characteristics are probably more crucial to motivation and are the curriculum materials used by teachers. It appears that the motivation potentially derived from laboratory activities has not been realized largely because textbook writers and teachers have failed to develop and utilize laboratory experiences for this purpose.

To what extent are your laboratory activities intrinsically or extrinsically motivating? Do you rely on laboratory report grades and/or tests on laboratory observations and conclusions for your primary sources of motivation? How have you prepared your students for your laboratories? Are they willing to put forth the effort necessary to solve the stated problem? To what extent do you provide opportunities for students to pursue investigations of their own design?

Examine each laboratory activity that you presently use. Assume that no activity is perfectly designed. Each was written initially for a mythical class that does not exist. Is the title of each laboratory activity in the form of a problem? Is the activity placed on a sequence that precedes or follows the concept that is to be "discovered" through the activity? Does the text explanation of the concept precede the laboratory experience? If so, how do you utilize the text? Rewrite each laboratory activity considering ways each can be modified to make it as exciting as possible for each of your students.

Laboratory experiences related to fermentation found in widely used biology textbooks, for example, are designed primarily to verify the by-products of the fermentation process--carbon dioxide, heat, and alcohol. Typically students are provided little, if any, intrinsic motivation for the activities problem focus, discrepancy, puzzling situation, novelty. Also, the concept is found in their textbook prior to the laboratory activity indicating a noninquiry instructional approach.

How can this laboratory activity be modified to make it more motivating for students? One strategy would include students observing bubbling in a sugar water-yeast solution (or grape juice-yeast solution). By asking students to identify hypotheses to explain the bubbling and reasons for the eventual cessation of the bubbling, students can design and conduct experiments to test their various hypotheses; e.g., oxygen or food (sugar) depletion, carbon dioxide or alcohol buildup, yeast mortality. For students to be able to pursue the testing of these hypotheses, they must have been provided prerequisite experiences with bromthymol blue (BTB) and limewater as indicators of carbon dioxide, methylene blue as an indicator for oxygen, and Clinetest tablets or strips as one test for simple sugars (Beisenherz, 1976).

As teachers increasingly utilize more open-ended activities during the school year, students should gradually achieve a greater expectancy for success and an increased confidence in their ability to behave as "bowlers" in seeking solutions to problems. By modifying several laboratory activities each year, only a few years will be required to conform your exisitng laboratory activities into a highly motivating, personalized set of experiences for your students. To alter each activity to maximize its motivational and instructional effectiveness is a tremendous task. But it must be done. Again, the teacher is the key!

## Competition

Teachers appear strongly divided on the use of competition in their classrooms. Competition can be useful if the student realizes that the learning task is not of great importance-- that losing will not cause problems with the class reward system. This role for competition will, it is hoped, result in intrinsic rather than extrinsic motivation (Wlodkowski, 1978).

"Who can make the strongest electromagnet?"

"Who can make the water rise the highest in the jar with the burning candle?"

"Given ten days and using any procedures you choose, who can grow the tallest bean plant?"

These problems, offered as individual or small group tasks, should result in heightened class activity, discussion, and enthusiasm. How can learning experiences be selected that are likely to achieve our instructional goals? The above discussion of instructional tactics appears consistent with Tyler's (1949) contention that consideration of student interests and needs be a primary concern in our daily decisions of how to select and utilize the many potential learning experiences at our disposal.

## TEACHER VARIABLES

From a multitude of teacher variables potentially affecting student motivation, two attributes appear to be closely identified with student motivation.

From work by Carkhuff (1969) and Gazda (1973), four teacher dimensions (empathy, respect, warmth, and concreteness) appear to be important in the development of student needs. In analyzing research studies on teacher characteristics Rowe (1977) found that caring was consistently ranked at the top of teacher characteristics considered important by students. Simpson (1978) concluded from these studies that "unless teachers can get in touch with students' feelings, and communicate to students their understanding and concern, proper relationships will not develop..." All of us who have heard Harry Wong speak at an NSTA Convention or know of his classroom teaching are aware of the importance he places on teacher characteristics related to the above dimensions. The implications of research on teacher characteristics for motivation and self-concept development of students seem obvious.

The second attribute is the ability of the teacher to model enthusiasm for the subject taught. Wlodkowski (1978) suggests that one of the basic motivational questions students ask (usually silently) about a subject is, "What does teaching this subject do for my teacher?" He further states that if we appear to our students to be bored, burned out, and, in general, just going through the motions, we have little opportunity of producing any positive attitude change in our students. How enthusiastically we feel and how well we can communicate our enthusiasm for what we teach is perhaps the greatest advocacy for science. Wlodkowski suggests that there "is a magnetic pull to know and understand what gives energy to the spirited teacher."

Would you predict that Carl Sagan (author and Professor of Astronomy, Cornell University) as a high school physics teacher or Hubert Alyea (Professor Emeritus of Chemistry, Princeton University) as a high school chemistry teacher would generate in their students a degree of enthusiasm toward science? What characteristics do Professor Sagan and Professor Alyea possess that motivate students? What reasons would describe Harry Wong's or Jearl Walker's classroom enthusiasm? How do we develop such enthusiasm? Can such enthusiasm be developed or is it a trait some teachers are "born with"?

Here lies an important point. As science teachers we cannot all model enthusiasm, empathy, and warmth as do Sagan, Alyea, and Walker. Whereas there are many Wongs, there is only one Harry Wong--science teacher! Although we might totally accept any one of the above individuals' educational goals, teaching styles, or programs, we often find it extremely difficult to role-play or model these efforts. For example, mixed feelings exist concerning the "success" of Wong's programs (Ideas and Investigations in Science Series, Prentice-Hall, Inc.) among those who endorse his philosophy and teaching style. All of us have unique personality traits, teaching styles, content backgrounds, etc. Some of us, for example, communicate to our students a greater warmth and concern for their feelings and needs. The fact that we are different suggests a partial explanation of Gallagher's (1967) conclusion that there is no such thing as a BSCS "Blue Version." There are as many "Blue Versions" as there are teachers. In fact, teacher characteristics are probably more critical than are specific curricular materials in achieving various instructional goals (Ramsey and Howe, 1969).

We have examined in some detail the first three questions identified by Tyler at the beginning of this chapter. For our purposes, his fourth question can be modified slightly to ask, "How can we tell if we are motivating our students?" Because motivation, like intelligence, is an "inferred construct" (Frymier, 1974), we must infer our students' motivation from their actions. The following provide some of the many formal and informal means of observing student motivation.

1) Obtaining scores on instruments designed to measure one or more of the various dimensions of student motivation. Keller and his colleagues (1978) have identified a number of these instruments.
2) Observing student behavior; e.g., the quality and quantity of questions, degree of participation in class activities, initiation of exploratory behavior, tolerance for ambiguity, appearance of enthusiasm (as operationally defined by the teacher).
3) Observing student involvement and extension of class activities in social issues, hobbies (preparation of skeletons, leaf or rock collections, birding) into the home or community.
4) Observing student involvement (on a voluntary basis) in science fairs.
5) Observing student involvement in science clubs and nonrequired courses, including second-level courses.

Often we encourage the brighter, college-bound student to participate in the special science experiences noted above. However, these "groupings" often provide a niche for students of all abilities who enjoy science, as well as the social nature associated with the club or class. To what degree do science teachers in your school offer such courses as clubs for students--for all students?

In examining collectively all of the above "evidences" of motivation, you can obtain a reasonable estimate of the motivational level with your classroom and school.

## SUMMARY

According to Tyler (1949), students should obtain satisfactions from learning experiences designed to achieve the stated objectives. Since his model was first introduced, there have been many ideas and "tactics" offered that should help students become more highly motivated. However, these ideas and tactics have not, for the most part, been integrated into classroom practice by science teachers. The implications for their use in the selection of our goals, objectives, activities, and evaluative procedures have been described. Hopefully, greater efforts to motivate our students in science will result in an increased enthusiasm for ourselves and our students.

The bottom line strongly suggests that to be motivating, enthusiastic teachers, we must daily select from our rack of motivational "spices" such a combination of "condiments" that will increase the intensity of effort put forth by our students. Our selection of the appropriate "spices" will determine if our students will want to return tomorrow to attempt new, more unfamiliar culinary delicacies. Berger states in another chapter that "teaching must be fun." If we truly work each day at providing students the maximum motivation possible, I submit that teaching will be fun!

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## WHY AREN'T WE DOING IT?

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### THE PROBLEM

I'm sure that I first heard the story from Sam Postlethwait, the founder of audio-tutorial instruction, but he denies it. Perhaps I make the association because both Sam and the story have roots in West Virginia.

The story concerns a West Virginia farmer -- others will swear he is from Kentucky, Missouri, Iowa, or Texas. The farmer was leisurely following his mule-pulled plow up and down the hill when the new county agent drove by. Seeing the sight, the agent stopped, thinking he had spotted the ideal candidate for his upcoming class on modern techniques of farming. The agent patiently waited while the farmer made another round, stopped by the fence to rest the mule, and freshened up the wad of tobacco in his mouth. Engaging the farmer in conversation, the agent gradually worked up to discussing the Monday night class. After hinting strongly about the wonderful improvements that the farmer might make once he knew what the agent had to teach, he extended the invitation: "Can I expect you at the courthouse next Monday, then?" The farmer chewed thoughtfully for a while, emptied the tobacco juice from his mouth, and replied, "Well, I thank ye' fer the invitation, but I don't reckon there's any point in <u>me</u> coming. Why shucks, I hain't farmin' half as good as I know how right now!"

And so it is in science education. Most of us only teach "half as good as we know how." (Only the woefully ignorant or superhuman teach as well as they know how!) Nor is our science curriculum half as good as we know it should be. This is clear from the reports of the three NSF Status Studies completed in the late 1970's and discussed by Professor Yager in an earlier chapter of this Yearbook. It is one of the sources of concern that led to the 1980 report to the president, <u>Science and Engineering Education in the 1980's and Beyond</u> (NSF, 1980).

Why aren't we doing better? Are we just now identifying the problems? You be the judge.

> The typical science curriculum in American high schools consists of ninth-grade general science, tenth-grade biology, and eleventh- and twelfth-grade chemistry and physics. While almost all schools offer these four courses, many require for graduation no more than one year of science. The majority of high-school students apparently meet the requirement by taking general science or biology. The reputation for being "hard" which chemistry and physics courses have acquired is all too rarely offset by a reputation for being interesting.... A substantial portion of students capable of doing well in physics and chemistry do not enroll in these courses.

...We must not lose sight of the fact that some basic understanding of the physical sciences and an appreciation of the scientific method have become an essential part of the education of the ordinary citizen. Henceforth, the needs of students who do not look to science for a career will not be met adequately by an exposure only to a course in biology or by a heterogeneous course in general science which gives them hardly more than glimpses of a number of scientific fields without allowing time for building up any real understanding.

...[O]bservation in classrooms throughout the country [has] revealed the following shortcomings that are common enough to be regarded as fairly typical of much of the science instruction in the United States today.

1. The science curriculums of American schools are too often non-developmental and repetitive. . .

2. A fault of many courses in science is that they attempt broad coverage at the expense of depth. . . [C]overage is superficial and affords little opportunity for critical thought...

3. . . .[S]cience instruction tends to be merely descriptive and involves too much rote learning. Class work and examinations usually stress facts rather than fundamentals, and rules rather than reasons. . .

4. The substance of many high-school science courses is too much concerned with technology and applied science at the expense of the fundamental ideas, concepts, and principles of science. ...

5. Very little is done to acquaint high-school students with the philosophy, history, and methods of science, or with its contemporary theoretical and experimental frontiers. . .

6. Laboratory work. . .is too often used only as a form of visual education rather than as a means of investigation. . .

7. Typically, a single text is closely followed to the virtual exclusion of reference work. . .

8. Special efforts to challenge and channel the abilities of science-gifted students are sparse. . . (AAAS and AACTE, 1960, pp. 5-8)

These recommendations were made by the American Association for the Advancement of Science and the American Association for Colleges of Teacher Education in 1960 rather than 1980, and AAAS and AACTE were not alone. The 1960 NSSE Yearbook echoed these sentiments:

Although a large portion of the citizens in our society have been exposed to science in the schools, the scientific illiteracy of the public mind is appalling. The products of science-teaching, as represented by the average citizen, are indeed disappointing. Science education in the future must break through to the behavior patterns of the "man in the street." (p. 153)

In some communities, uninformed citizen groups have brought ill-advised pressures upon the schools with such slogans as "Let's go back to the good old days." (p. 154)

> Many criticisms directed toward the objectives of science-teaching are actually a censure of classroom procedures which fail to realize those objectives; for example, methods which demand too many facts, too little conceptualizing, too much memorizing and too little thinking. (p. 34)

These quotes (with the exception of point 4 of the AAAS-AACTE observations) might have come from the recent NSF Status Studies, but they were from studies conducted 20 years ago. According to Carleton, then the Executive Secretary of NSTA, they might have come from still earlier studies.

> For almost 40 years there has been general agreement, in theory at least, regarding the purposes of science teaching. However, studies by Beauchamp and Obourn reveal that little has been done in science classrooms across the country to attain some of the most important of these purposes. (NSSE 1960, p. 152)

If many of the problems outlines by Dr. Yager in Chapter 2 have been with us for 20-60 years, why haven't they been solved? What hope is there that they will be solved now? Why are we only teaching "half as good as we know how"?

## THE TYLER RATIONALE

In the late 1940's Ralph Tyler prepared a syllabus for his curriculum course at the University of Chicago. The syllabus was published in 1949 and has been used as a basic reference in curriculum courses ever since. Tyler's influence is clear from Fenwick English's comments:

> To practicing school people who must be responsive to minimum competencies, statewide testing mandates, efforts by the states and the feds to apply standards of quality assurance to schooling, taxpayer resistance, and public scrutiny, the "Tyler rationale" is the only one that gets results. It is used because it works. As Peter Drucker once observed, "Management is practice. Its essence is not knowing but doing. Its tes is not logic but results. Its only authority is performance." (ASCD Update 1980, p. 4)

But in spite of its longevity and in spite of English's enthusiastic endorsement, after 30 years of the Tyler rationale we find that science education is still faced with most of the concerns voiced 20-60 years earlier. In science education things still "ain't half as good as we know they should be." If we honestly want to do better, we must first look for conditions that prevent us from doing better. What are they?

### Reasons for "Failure"

The teacher's task is humanly impossible. This may appear to be an overstatement, but I don't think so. Even a cursory examination of Tyler's Basic Principles of Curriculum and Instruction (1949) will reveal the complexities of effective teaching.

Ignoring for the moment the difficulties of arriving at consensus concerning what should be taught, let us consider the teacher's task in the classroom.

1. No activity can be a learning experience without active participation on the part of the student. Thus, effective teaching requires that the teacher know what will interest adolescents and must use that knowledge to channel interest toward the goals that have been set. This will require skills of performance as well as the knowledge of student interests.

2. Once a skill or idea has been presented, opportunities to practice the skill or use the idea must be provided so that retention and transfer are enhanced. Care must be taken in planning practice so that interest is maintained and so that unintended, erroneous messages are not conveyed.

The importance of the latter point is seen in Battino's polemic, "I Hate 22.4!" (Battino, 1974). Discussion of molar volume is usually limited to the volume of a gas at STP, 22.4 liters. Since no other values of molar volume are encountered, students tend to miss the significance of the specified temperature and pressure. Consequently, they frequently arrive at the naive notion that a mole of a gas occupies 22.4 liters . . .period!

3. If students are to persist in a learning activity, the activity must lead to satisfaction. Thus, teachers must be sensitive to student reactions to instruction and make instruction satisfying while making it useful.

4. Learning activities can never be satisfying if the activity is not within the range of possibility for the student. At various times a task may be impossible because of the emotional state of the student, the level of intellectual development that the student has attained, or the amount of prerequisite knowledge that the student has acquired. Thus, effective learning requires that the teacher know both the intellectual demands of the learning task and the intellectual and emotional state of the student. Since the intellectual and emotional states of students will differ from one to another, truly effective instruction requires that this assessment be done on an individual basis.

5. Since no practical classroom situation is likely to allow for perfect execution of step 4, the teacher must be sensitive to different outcomes that my result from the same experience. Words and observations will be interpreted differently, depending on the background and mind-set of the student. Johnstone (1980), for example, cites examples of students associating "smallest volume" with "most concentrated," apparently as a result of their everyday experience with "concentrated" orange juice. He also cites examples of students interpreting "fused" to mean "extinguished" because of the expression in Britain that "the lights are fused" when they go out as a result of an electrical fuse melting.

I recall a ninth-grade girl who deduced that we live on the inside of a hollow, spinning sphere and are able to stay on the surface of the earth for the same reason that water stays in a bucket when it is spun in a circle at the end of our arm. Another student and I argued for half an hour about an electrolysis demonstration before it became clear that my words, "The hydrogen and oxygen gas came from the water," had meant to the student that the gases were dissolved in the water rather than that the water disappeared and the gases appeared in its place.

A related problem requiring attention to unintended outcomes is the poor attitude that may develop along with successful skill development, or the unrealistic picture of what life as a scientist may be when only "fun" things are done in science class in order to keep interest high.

6. The teacher must be prepared to provide different experiences for different students in order to allow for their different abilities and different goals.

7. Since there are many goals of instruction, the teacher must keep track of development in many areas.

8. Many important goals such as "thinking skills" and skills related to independent learning develop over a long period of time. Consequently, the teacher must organize instruction so that such long-term goals are fostered, and evaluation must be devised to monitor such development.

9. Knowledge and skills that can only be applied to answer questions on a class exam are of no lasting value. Thus, effective teachers must know what affects transfer of information, they must plan instruction to enhance transfer, and they must devise evaluative tools to see if the knowledge is transferable.

10. Since teachers are working with children and adolescents rather than adults, they must attend to the development of acceptable social attitudes (being on time, being responsible, respecting the rights of others, etc.) and to personal adjustment (positive self-concept, ability to face reality, coping with stress, etc.) as well as teaching a subject. Teachers frequently perform other tasks which require skills in personal counseling, financial management, personnel management, and so forth, but these skills are generally applied outside of the classroom and are not mentioned here.

The foregoing list derived from Ryler's book is certainly incomplete, but it should be sufficient to show that excellence in teaching requires knowledge and skill in many disciplines as well as the capacity to simultaneously attend to a multitude of concerns.

The kind of teaching that we know how to deliver under ideal conditions requires a level of preparation on the part of the practitioner that is comparable to the level of preparation of a research scientist or a medical doctor. Furthermore, the demands for rational thought and decision-making for the best possible teaching are equal to the demands on a research scientist and medical doctor, or similar professional. Still further, support services comparable to those available to other professionals are needed if a teacher is to deliver the highest possible quality of instruction.

At the present time the intellectual capability of teachers is below that of students entering other professions (Weaver, 1979), the length of training is too short to teach what is known, and teachers operate with few support services.

The School's position within the greater social structures makes success impossible. This point was made eloquently by Matthew B. Miles in an essay published by National Training Laboratories (Miles, 1967).

The following discussion draws heavily from Miles' essay. First consider the difficulty of deciding what is "good" for children and the role of the school in accomplishing it.

We can surely agree that schools exist for the purpose of bringing about desirable changes in children; we probably could not agree about what is desireable! However, children are not the exclusive property of the school nor is the school the only agency charged with bringing about desirable changes in children. Parents "loan" children to schools as well as to churches, volunteer agencies such as Scouts or 4-H, various clinics, and summer camps where they expect various desirable changes to take place.

Once a child has been loaned to the school, the parent has little direct knowledge of what happens to the child. Feedback is limited to what children report, what can be inferred from assignments and test results, and what a report card with a uniform letter code but a nonuniform interpretation for the code show. By contrast, a parent frequently accompanies a child into a doctor's office; is invited (or required) to share the child's experiences in volunteer groups such as Scouts or 4-H; and may supervise, plan, or share the child's experience in church.

Even though the school shares with parents, the church, courts, and various social agencies the responsibility for bringing about desirable changes in children, these agencies operate independently and often at cross purposes. There is not structural linkage among these agencies, and there are often legal constraints to informal linkage. Tyler addresses this issue at some length.

> In many modern communities there is disjunction between the school and the home, the school and the church, the school and the rest of the community with regard to the attitudes that are developed. The environments are inconsistent; values, points of view are taken for granted in the press that are denounced in the pulpit, the values emphasized in the motion pictures are in conflict with those which the school seeks to develop (Tyler, 1949, p. 76-77).

While there are not structural connections among the various agencies that assume responsibility for the socialization of children, there are informal linkages that constrain and influence the operation of schools. Recent court decisions which extend the traditional rights of adults to children have placed real and imagined constraints on schools. Accreditation agencies, state departments of public instruction, and the federal government place legal and quasi-legal constraints upon the operation of schools. Colleges and professional schools, testing organizations, and special interest groups exert additional pressures.

Clearly schools operate in a complex environment influenced by a large number of relevant publics with disparate and often conflicting goals and interests. It is impossible to satisfy the legitimate concerns of every group with a vested interest in the operation of schools.

Existing Conditions Require That Schools Fail.

Ignorance is safer than unpleasant truth; sometimes lies are even safer. It should be plain that truth is not highly valued. We are taught that it is better to lie when the truth may be embarrassing or result in personal harm. Euphemisms are not only tolerated but actively encouraged. People "pass away" rather than die and become "sanitation engineers" rather than garbage collectors; we "strengthen our defensive posture" rather than buy more weapons, and "provide negative reinforcement" rather than punish a child.

Modern advertising is based on intentional misrepresentation of truth, and schools of business actively teach students to use such deception. One modest example of such instruction is seen in the following excerpt from a news account concerning a psychologist and business consultant, an expert on firing and being fired.

> Make sure to work out a good cover story with your (ex-) boss. To colleagues, friends, neighbors and future employers, you are never fired. You simply resign to look for new opportunities. (Goldberg, 1981. p. D-3)

This propensity to encourage deceit and disrespect for truth causes serious problems for educators. It is especially bad for science educators who try desperately to swim upstream, telling students that absolute, objective truth is essential in science, even when it hurts.

But what has this to do with schools as social institutions? Since the impossible demands placed on teachers ensure that they will fail -- at least in the eyes of some -- and since the impossible conditions under which schools operate ensure that schools will fail -- at least in the eyes of some -- and since our society readily accepts that it is better to hide or obscure unpleasant truth rather than accept the consequences of that truth, we hide the truth a lot.

What are the screens that avoid truth in the operation of schools? There are numerous ways that we are able to avoid facing truth. Numerous screens are in place and operating effectively. I mention only a few.

In examining the following list of practices, the reader will observe that there are legitimate reasons for many of the practices mentioned; i.e., they are not in place just to hide truth. However, it should also be recongized that the effect is the same; the practices serve to protect us from painful truth and interfere with the improvement of science education.

> Educational goals are usually (a) vaguely stated; (b) multiple in nature, since the school is expected to do many different things to meet the wishes of its many publics; and (c) conflictful, in the sense that different publics may want mutually incompatible things (Miles, 1967, p. 6).

Keeping goal statements vague is one way to avoid the truth of what we hope to accomplish and to protect ourselves from the wrath of one or more of our publics. It may also be beneficial to limit our objectives to those that are most easily accomplished.

Science educators have long stated (and probably believe) that critical thinking, problem solving, and inquiry skills are more important than learning isolated bits of factual information. However, the former skills are developed over a long period of time, are more difficult to accomplish, and present problems of assessment. By contrast, it is relatively easy to produce short-term gains in verbal performance on rotely learned information. There is far less personal threat to a teacher who emphasizes knowledge-level goals because it is easy to demonstrate that "learning" has occurred. Overwhelming evidence is available to teachers (but is probably less well known to parents) that such learning is of short duration and of limited value for transfer to nonacademic settings. But, good performance on trivial objectives is likely to be less threatening to the welfare of the teacher than is poor performance on significant objectives.

Another effective screen is grade inflation. Students who receive good grades, and parents of children who receive good grades, are unlikely to ask embarrassing questions about understanding. They may even believe that there is understanding. It should be noted that grade inflation protects everyone: teachers, students, parents, and administrators. So long as we pretend that performance is better than it is (or that effort, attendance, good manners, or nonproductive activity is just as important as accomplishment) we can avoid facing the difficult question of why performance isn't better and what can be done about it.

> Self selective processes occur in the recruitment of teachers for the American public school; persons who are less verbally able, more passive, more deferent, and less competitive than other professionals tend to enter teaching jobs (Miles, 1967, p. 18).

We may add to Miles' list that many teachers enter the profession without the knowledge of the subject they are to teach or the competencies in learning psychology and social psychology that they need to operate effectively. Existing certification requirements based on courses taken rather than competencies held perpetuate the problem. These procedures protect teachers from possible loss of financial investment and universities from potential embarrassment. Similar protection is provided by a salary schedule based on years taught and courses taken rather than on the basis of performance.

Teachers are further protected and the reputation of the school is protected by minimizing the opportunities for adults to observe teachers doing their job. There are far fewer opportunities for teachers to observe teachers, for parents to observe teachers, or for administrators to observe teachers, than would be the case in industry or other professions.

Actually there is nothing to prevent administrators from observing teachers and supervising them. However, doing so obligates the administrator to act on what is learned, and the actions taken -- rewarding those who are effective and helping or firing those who are not -- is either precluded by salary schedules and work rules negotiated by teacher organizations, or may lead to criticism and unpleasantness for the administrator. By choosing not to visit teachers and thus not "knowing," the adminstrator is protected from such difficulties. Thus, the sponsoring public has far fewer opportunities to judge teachers on the basis of actual performance than would the the case of police, firemen, judges, and others in service professions.

Conditions that control teaching effectiveness are influenced more by financial considerations than by pedagogical considerations. America is materialistic. The preeminent value in our society is to make money. For the majority, all other considerations take second place. It is doubtful that schools would be supported at all if there was not the common belief (supported by considerable evidence) that education has monetary benefits. There has never been strong sentiment in this country for the values of a liberal education; i.e., learning that cannot be turned into dollars. In spite of a general belief that education results in financial gain, the connection is often tenuous -- far more tenuous than the connection between education and its direct costs.

There is little point in discussing the obvious problems associated with school funding. They are well known. However, there are other, less obvious ways that our materialism affects science education. One of the most important is in textbook publishing. The single most important tool and the second most influential component of the classroom environment (the teacher is first) is the textbook. In the United States, the textbook is the curriculum, curriculum guides notwithstanding. If one wants to change what is taught in science, one must change the textbook.

Few science educators are happy with science texts. Perhaps even fewer authors are happy with the texts they supposedly authored. (Supposedly is intended. Authors of school texts typically exert minimal control over the content, organization, or design of the text they "write.")

Publishing companies are profit-making corporations. Their reason for existence is to make money for shareholders; it is not to provide the best pedagogical tools for classroom teachers. Presumably, those publishers who do provide the best pedagogical tools will make more sales and more profit, satisfying the needs of both buyer and seller. However, this is probably not the case.

Individuals in decision-making positions at publishing houses generally have backgrounds in sales and marketing but not in learning theory. Publication of a school book can represent a half-million dollar investment, and such investments are not taken lightly. What has sold well in the past will influence the publisher's decision more than what an author claims is needed in the future. Publishing a text for a course that is well established in the curriculum involves fewer risks than developing materials for courses that should be offered but are not.

This conservative attitude and marketing focus seriously impede curriculum revision. Science teachers are busy. Most meet five or six classes of two or three subjects each day. Some science teachers must prepare for as many as five different subjects and supervise extra-curricular activities after school! With such schedules it is totally unrealistic to expect the majority of teachers to develop their own curriculum materials. They must rely on textbooks as the major source of information and as a guide for instruction. They have neither time nor energy to develop their own. (There are exceptions, of course, but good marketing aims at the masses.) Thus, if there are no suitable text materials for a new course (or for an old course shifted toward new goals), teachers are reluctant to make changes, no matter how much they may believe change is desirable. Better to stick with the standard course than to chart a new one with no navigational aids.

Then how can the teacher get materials for a new course? Publishers will not invest in a book with no market. First, they must see the enrollment figures that translate into potential sales.

Even the market research that publishers do perpetuates the status quo.

<u>Typical Question</u>: "Why did you select the text you are now using?"

<u>Typical Answer</u>: "Because the cover looked more durable than the others."

<u>Publisher's inference</u>: "Durability of covers is an important consideration in selecting books."

<u>Teacher's Thinking</u>: "There isn't any important difference in the seven books available to me. I may as well get one that will last!"

<u>Typical Question</u>: "What topics do you cover in your course?"

<u>Typical Answer</u>: "Atomic structure, the mole and stoichiometry, acids and bases, equilibrium, . . ."

<u>Publisher's inference</u>: "These are the topics that should be stressed in the new book we are planning, because they are the ones teachers stress."

<u>Teacher's Thinking</u>: "These are the topics in the text we adopted, and I don't have time to make changes."

State textbook laws often constrain publishers. Persons on state textbook commissions are often lay persons appointed by politicians to make decisions for political reasons. (This does not <u>necessarily</u> mean that "favors" are provided to particular sales representatives. A "creationism" text may be included on a state list in place of a more highly regarded text in order to placate a particular political group, and selections may be made in order to "spread the wealth." For example, it was reported that Holt, Rinehart, and Winston was given the choice of having either <u>Modern Physics</u> or <u>Project Physics</u> on a state list, but not both. It was argued that it would "look bad" if Holt had two books on the list while another company had none.)

The point is that political and marketing considerations exist which influence publisher's decisions far more than do pedagogical considerations. Authors are frequently coerced into adding topics, changing order, deleting material, and altering format in such a way that the resulting text does not represent what the author knows to be sound science education.

<u>"Should" outweighs "can" in educational thinking</u>. Because schools are often viewed as the transmitter of the ideal culture, educators tend to lose sight of reality and, like Don Quixote, joust with windmills. Witness the present volume: how much space is devoted to things that <u>should</u> be compared to things than <u>can</u> be?

Professional organizations, principals, school boards, educational researchers, and the general public habitually cajol teachers in an effort to "motivate" them to "do better," but little is done to alter the conditions that limit teacher effectiveness.

It is more difficult to change people than to change things.

> As Lippitt (1965) points out, the adoption of educational innovations often turns out to be relatively difficult, since the innovations involve human interaction and often require active learning or retraining of the operative, so to speak. The diffusion of behavioral innovations is a much more difficult matter in schools than in systems in which physical technology is the item being diffused (Miles, 1967, p. 10).

Several impediments to innovation in schools have already been mentioned; a few additional factors are mentioned here to emphasize the magnitude of the problem.

1. The enterprise is large. According to the latest digest of Education Statistics, there are now approximately 47 million children, 2 million teachers, and 200,000 administrators in elementary and secondary schools. (Grant and Eiden, 1980)

2. Compounding the problem of size is the lack of tight interdependence among individuals in schools. Within a school, the fate of one teacher is not closely tied to the fate of another. There is little sense that one's personal success or failure is directly tied to the success or failure of the teacher next door. Similarly, schools within a community tend to operate more-or-less independently; the "good" school in the system is not unduly affected by the "bad" one. And so it is with school corporations and state systems.

Although the independence of each educational unit has certain advantages when one wishes to experiment with a small number of students, it makes it difficult to introduce a proven innovation on a grand scale.

3. Ultimately, school policy is under the control of a lay board. Whatever advantages this may have in general, it probably impedes innovation. Such individuals are likely to be far removed from researchers and may find it difficult to understand the arguments in favor of educational change.

Probably more significant than the distance from researchers is the separation of the board of education from the classroom teacher. Historically, many teachers had little training beyond the grade that they taught. An experienced teacher acted as principal or superintendent. He selected textbooks, planned the curriculum, and counseled the novice. He also stood between the teacher and the governing board of the school, protecting the teacher from unjust criticism and representing his/her interests to the board. The system was paternalistic, but many of those in charge of classes needed such parental protection. Times have changed. Schools are larger and more complex, teachers are far better trained, society expects more of the schools, and society itself is far more complex.

Principals and superintendents no longer represent the interests of teachers to the governing board. Often the only contact between teachers and the policy-making board is through collective bargaining, and the atmosphere surrounding such meetings is seldom conducive to cooperative planning for educational change.

Readers will undoubtedly think of additional conditions that exist in American education and which, in concert, prevent us from teaching "half as good as we know how."

## WHAT CAN BE DONE

It should be clear that changing educational practice can be extremely difficult, and even though Ralph Tyler's rationale for curriculum development may be sound, it is incomplete. In addition to considering what goals are proper, we must consider what goals are possible; in devising the strategies to accomplish goals, we must not lose sight of real barriers that limit our activities; in evaluating outcomes we must guard against doing simplistic evaluation that masks our failures, or setting unreasonable standards that hide the accomplishments that are made. In such a spirit of realism, it would be foolish to suggest action that would be appropriate for every teacher or every school system, yet it would be irresponsible to outline problems without suggesting the direction to be taken for solutions.

1. First, we should acknowledge that the nature of the educational enterprise and the nature of those who run it lead us to focus too much on what should be and not enough on what can be. We must make reality-checking a standard and deliberate part of every goal-setting activity. In effect, we must add to Tyler's suggested guidelines for establishing curriculum goals, a third screen: Under prevailing conditions, is it possible?

When a particular goal appears to be improbable because of limited resources, underprepared teachers, or lack of community support, the goal should be discarded or placed on a "someday" list for reconsideration when conditions change. When there are more goals than can be accomplished -- a likely condition for the first, second, and third lists made -- we must keep working until the list is pared to a reasonable length. When efforts are made to place new burdens and responsibilities on schools, teachers, administrators, and school boards must resist the effort by assisting in the search for other agencies to handle the task.

Until we are far more realistic about what we can do, we will never accomplish what we should do.

2. One of the things that we can do is insist on the truth. We can be truthful with our students. We can be honest with parents. We can object to euphemistic language and refuse to use it ourselves. We can discourage our students from using euphemisms and vague expression.

If we are to encourage truth, we must be ready to accept some unpleasantness and prepare our students for the same. An evaluation by a principal or department head that suggests areas for improvement need not be seen as a vote of no-confidence, and a grade of C need not be taken as an indication of failure. None of us enjoys facing shortcomings, but there is not evidence that ignoring them leads to their demise. To the contrary, it is only through honest appraisal and concerted effort that improvement comes.

In the past decade our mood has been to protect individuals from even the slightest hurt. Our strategy has been to insulate indi duals from those truths that prick the tender skin; we can work at developing more calluses.

3. One of the first truths that we should face is that capitalism is alive and well in the United States, that capitalistic goals require publishers to make a profit, and that focus on profit influences the nature of curriculum materials. Although publishers may not assign high priority to producing materials that are pedagogically sound, they do not object to doing it. They just need assurance that doing so will not decrease their profit. It is up to science educators to show how it can be done.

4. Perhaps the least tractable problem that I have cited is the disjunction between the school, the home, the church, and other social agencies that share a concern for children. On the surface the solution is clear: Establish an organization to set social goals, to assign to various groups responsibility for achieving those goals, and to coordinate the activities of the various groups and to keep track of individuals who move from one group to another for help. On the surface that is the solution, but obvious social engineering doesn't always work. I defer to those who know more about politics and sociology for a solution, but real progress in schools must await their solution to the disjunctions cited.

5. Finally, and most important, we must give teachers more control over school policy. Teachers must have more to say about the conditions that limit their ability to teach and build curriculum. They must have more control over school policies and budgeting, and they must feel directly the effect of bad decisions.

Everyone knows that a school with outstanding teachers is an outstanding school, no matter what, and a school with poor teachers is a poor school, no matter what. Giving teachers power to control their own fate will not automatically make schools better, but great strides cannot be made until teachers sense that they "own" the problem of schools and have the power to generate solutions.

I have two suggestions for providing teachers with more power. First, I would recommend that at least one teacher be made a voting member of each school board. School boards need input from teachers, and teachers need direct knowledge of factors affecting school policy. No matter what policy the board adopts it is unlikely to be effective unless teachers work to make it so. Furthermore, every policy adopted by the board affects the morale and effectiveness of the teachers. If schools are to serve communities well, board members and teachers must cooperate. How can they cooperate if there is no opportunity to communicate? Having a teacher as a voting member of the board should facilitate communication; with thoughtful representation it should promote understanding.

I have said that teachers are the key to effective schools, but the <u>one</u> person who can change a school most is the building principal. If the principal is an effective leader and has faculty cooperation, a great deal can be done; if the principal is an ineffective leader, morale will be low and even an excellent faculty will provide mediocre education. For this reas ., it is imperative that the faculty have confidence in the principal, and the best way to ensure that this will occur is for the principal to serve only at the pleasure of a the faculty.

Some elaboration on this point is in order. A principal of a school has great power over teachers. He/she controls class assignments. He/she evaluates teacher performance. He/she processes requests for supplies and equipment. He/she determines what students are assinged to a teacher's class. He/she controls the public address system. Such power affords great opportunity for abuse, as any teacher interrupted in the middle of class by a trivial announcement will readily attest. Even when there is no abuse, the potential for abuse and its concomitant fear persists.

Our founding fathers knew the danger inherent in unbridled power and established checks and balances which would protect individuals from abuse. Teachers need similar protection from abuse of power by a principal. The power to remove a principal by a vote of no-confidence would constitute such a check. It would encourage a principal to consult with the faculty about school policy, to understand faculty concerns, and to consider their solutions to problems. His/her welfare would depend on it. As things are now the principal pays more attention to the superintendent and the board, because his/her welfare depends on keeping them happy rather than keeping teachers happy.

6. Just as teachers need the protection that could come from power of dismissal over their principal and effective representation on the board of education, the public needs protection from abuse of power by teachers. Of all governmental services, education is the most costly, and a child is a parent's most precious possession. The public has a right to know that their money is well spent and that their children are well served. Thus, long-term evaluation of educational goals must be made an essential part of every school program.

Research and development at the local level is virtually nonexistent in education. Miles estimated that

> [no] more than a dozen school systems in American have anything that might be called a systematic research and deveopment unit to develop new practices, test these for feasibility and efficacy, and aid in diffusing them to various parts of the system. In addition, institutionalized change-agent roles analogous to those of the engineer, the field tester, or the county agent seem to be underdeveloped or lacking in the traditional American system. (Miles, 1967, p. 17)

The lack of a well-developed strategy for long-term "product" evaluation of schools causes serious problems. There are substantial pressures on schools to be "accountable." Charges that schools and teachers are not doing their job must be answered one way or another. In the absence of long-term evaluation of significant educational outcomes, there is almost irresistible pressure to work toward gains on less educationally significant measures such as grades, short-term test results, and a number of students who are admitted to college.

If teachers are to resist ill-advised attempts to change curriculum, they must be armed with information to bolster their arguments that significant, long-term goals can be accomplished and that the importance of gains in these areas outweighs short-term achievement of less significant goals.

To my six suggestions for what can be done to improve science teaching, the astute reader can probably add sixty. If these things are somehow done, will we no longer teach only half as well as we know how? Probably not. We will know more, and we will see new barriers in the path to new goals. We'll still only teach half as well as we know how, but we'll teach twice as well as we do now!

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# ONE STEP AT A TIME, BUT PLEASE HURRY

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## INTRODUCTION

Readers committed to keeping abreast of what is happening in science education and education in general are most likely finding their reading very distressing. Coping with stress, teacher burnout, and unsettled labor negotiations dominate the general literature. In science education we must face the fact that the massive curriculum efforts of the Sixties are being placed on the back shelf. That laboratory science which was to excite every student frequently bores more students than it excites. And, the back to basics movement has everyone so much involved in teaching reading, writing, and computation skills that no time remains for teaching the science that would allow students to use these basic skills to solve significant and exciting problems. Students are unruly, SAT scores are declining, enrollments are falling, and spiraling inflation is stifling innovative thinking. It appears to be a dismal time and, as usual, there are many persons willing to lay the entire blame on education. But is it really all bad?

Ralph Tyler (1976) stated that, "The quality of American education, then, as judged by several kinds of evidence, has improved since 1950, but the attainment of our long-term goals still lies ahead" (p. 71). Other sources offer similar conclusions. These include the Department of Education, The National Science Foundation, and numerous independent researchers.

The status report jointly prepared by the Department of Education and the National Science Foundation argues that we remain capable of producing the best trained scientists and engineers in the world (Hufstedler and Langenberg, 1980). Their projections indicate that we will have an adequate supply of competent scientists in most fields at the beginning of the 21st century. Shortages projected are in computer science, statistics, and some engineering areas. From reviews of our past history we can predict that because these potential shortages have been identified we will step up our efforts to encourage our bright young students to pursue studies in these areas. As Tyler points out, the career orientation of youth is stimulated by economics, by laws of supply and demand that will make careers in the areas increasingly more attractive (Tyler, 1976).

The Education/NSF report clearly allows us to conclude that we have been and are doing an excellent job preparing future scientists. However, the report continues, leading to a conclusion similar to that of the other status reports, including Professor Yager's chapter, that we are failing to provide our general population an adequate science background (Hufstedler and Langenberg, 1980; NSF, 1979). While these reports are frightening, we need not despair because there is evidence that we can cope with this problem, given adequate resources.

Evidence supporting this optimism stems from individual research reports. For example, process-or activity-oriented science instruction provides a means for developing the basic skills needed in both language arts and mathematics. Rowe (1973) discovered that the amount of student-initiated content-relevant speech in ten Harlem classrooms was 200 to 500 percent higher during science classes than during language arts classes. Similarly, Ayres and Mason (1969), Hugg and Languis (1973), and Renner and Coulter (1976) all have found that young children involved in process/activity-oriented science courses make considerable gains. In yet another study, Quinn and Kessler (1977) found that when children are given practice formulating hypotheses, their language becomes syntactically more complex. And, Tyler (1976), in his summary of critical problems, indicates that children encounter few problems that need professional attention. They merely require opportunities for stimulation, for practice, for feedback, and for continued use of what is learned.

Admittedly, these reports are few in number but there is additional evidence. Professor Donald McCurdy visited over 100 schools during his year as president of The National Science Teachers Association (1980-1981). He talks in glowing terms of all the excellent teaching and local curriculum innovation occuring across the nation. Like most of us in this profession, he admits that some teachers are seemingly waiting out a retirement that won't take place until the year 2010, but that stereotype is inappropriate for most science teachers. My recent experience with teachers of the students who participated in the Space Shuttle Student Involvement Project allowed me to similarly conclude that many science teachers will never become victims of "teacher burnout."

This leads one to ask: What is the difference between the "haves" who are continuing to motivate learners and the semi-retired "have beens" or "never have beens?" It is my impression that the "haves" treat their science teaching as an inquiry or an artfully applied science. They are, like Tyler, continuing to ask questions. Questions such as those posed by Tyler in 1949, which are:

1. What educational purposes should the school seek to attain?

2. What educational experiences can be provided that are likely to attain these purposes?

3. How can these educational experiences be effectively organized?

4. How can we determine whether these purposes are being attained? (Tyler, 1949, p. 1)

Tyler's questions continue to be useful guidelines for the successful science teacher. These teachers gain their success from their search, their continuing inquiry into science teaching. Like the Three Princes of Serendip whose faculty for making desirable but unsought discoveries that gave us the word serendipity, these teachers continue to improve throughout long careers. But what about those teachers who cease to search, or never begin, and hence never feel the excitement of discovering a means to motivate the unmotivated to practice and learn?

Mary Budd Rowe's 1973 classification of people as "crap shooters" who don't think they can influence outcomes, and "bowlers" who believe that they create their destiny, should be considered. Are perhaps the "have nots," or "do nots" the crap shooters of our profession? If so, how many of our profession would be so classified? And, can something be done about it? What? Can we, should we, send them out to pasture early, or would we seek a means to change them as we hope to change the behavior of students left in our charge?

When I was a child I frequently heard a poem that went something like this: Because of a nail a shoe was lost, because of a shoe, the horse was lost, and because of the horse a rider was lost. The poem proceeds to the logical conclusion that a war was lost because a single nail fell from a single horse's shoe, which, to anyone's thinking, is a trivial reason for losing a war. Experienced teachers realize that students frequently can not solve complex problems for reasons equally trivial, and it is reasonable to assume that teachers fail to teach for equally trivial reasons.

Searching for answers to Tyler's four questions is a reasoned approach to identifying both the significant and trivial elements of science curriculum and instruction.

## FIRST GOALS AND OBJECTIVES, THEN CHANGE

Tyler's first question is: What should be the goals and objectives of the science curriculum? To obtain an answer he suggests that you examine three sources; i.e., (1) the learner, (2) contemporary life outside the school, and (3) subject specialists. Then, filter the objectives so obtained through psychology to identify the attainable and through philosphy to eliminate the inappropriate and trivial.

The science curricula of the 1950's were described by Schwab (1963) as a rehetoric of conclusions which tended to portray science as a completed task rather than an active ongoing pursuit in which students could be involved. Plans for reformulating the curriculum were well underway by the mid fifties (Henry, 1960). Sputnik's flight stimulated the creation of massive federal support for science curriculum development, and subject matter specialists readily accepted the assumptions that children are inherently scientific and that a science curriculum consisting of really "good" science, science as it is practiced by scientists, was what this country needed if we were again to be world leaders in science and technology (Bruner, 1962).

The laboratory-oriented curriculum materials developed by the subject specialists and the concurrent teacher training institutes were considered, by most, to be excellent. In the words of Tyler (1976), science became among the best taught subjects. However, all too soon it became evident that the new curriculum was not universally better. While few stated it, a viable explanation for its lack of success is the fact that the curricula were essentially derived from one source instead of three and the psychology/philosophy screens were more token than real. Unfortunately, because it was not better for all, many teachers became disenchanted with the new curriculum and returned to the rhetoric of conclusion, read-about science approach which interests even fewer students in science.

The first step must be to develop that overall listing of goals and objectives, and this must be done with specific students in mind. First let's consider the interests of students. Tyler indicates that if you want to motivate a student to learn, the best place to begin is with their interest. "Interest" he said, "is the point of departure" (1940, p. 11). We must remember that science as it is practiced by scientists is not interesting to all students. Varieties of curricula, designed to match their interests, are needed. In earlier articles, I identified six interest dimensions of science that could serve as portals of entry to the study of signficant science. These are illustrated in Fig. 1 (Andersen, 1977).

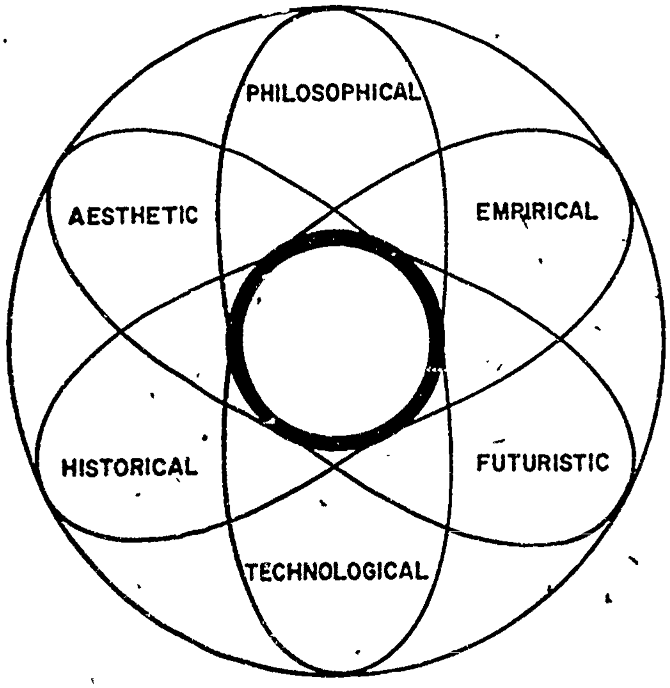


Figure 1. A Holistic Model

The model portrays each dimension of science as an ellipse that overlaps all other dimensions. The overlaps represent the core of science. The core science is the science a person needs to be an effective citizen in our technological world. A student's study of science could begin at his point of greatest interest and proceed inward to where the dimensions begin fusing together and then in all probability outward again toward mastery of a second, third, etc., dimension of science. For example, a student with a historical orientation could begin his studies by examining histories of scientific inquiries. As the student's study proceeded it would interface with the technological dimension of science. A study of the history of the technological dimension of science might stimulate other interests and so on. The point is, some study is better than no study. Identify the student's interests, discard the outdated notion that the best place to teach all students science is in the science laboratory, and involve the student in the dimension of science that interests him or her. (For some, and perhaps many, this will be the laboratory.)

The second source of objectives is contemporary life out of school. It has been stated that the problems which people will face in their life time and which a knowledge of science would help them solve are known. Furthermore, curricula emphasizing a search for solutions to people problems have been used successfully. In fact, Sonneborn (1972) argued that the personal problem-solving approach is often more interesting to many students, and in all likelihood students involved in science courses with this orientation could learn as much "good" science as students in the "good" science courses who are studying science as it is practiced by scientists. While contemporary problems were largely ignored when objectives for the curricula of the sixties were designed, the major problem of the period was our belief that we had fallen behind in science technology. The lesson learned is that focusing on a single contemporary issue limits the useful lifespan of the material developed. Avoiding a single issue must be a major consideration when developing a curriculum for national implementation. However, the precaution should be ignored by teachers in local settings who are developing curricula to benefit learners with exposure to the "hottest" contemporary issues involving science.

Subject matter specialists are the last source to consider for objectives. Admittedly, they are needed to determine accuracy of the curriculum and to assist in defining the goals and objectives for those students whose interest is pursuing a science career. However, many specialists cannot separate their thinking from the path leading to their specialization. As a result, they will, as Tyler warned, tend to prepare a curriculum leading students to a science career rather than a curriculum that will prepare students to be citizens able to discuss science issues intelligently. Recently published status studies and Professor Yager's chapter strongly indicate the need for new science curricula aimed specifically at preparing scientifically literate lay persons (Harms & Yager, 1981). This curriculum would involve students in examining contemporary issues involving science, as Tyler suggested 30 years ago. The list of objectives produced by carefully studying the interests of students, contemporary science issues, and the suggestions of the subject specialist should then be screened through psychology and philosphy.

According to Tyler, the psychology screen is needed to help one decide what objectives are attainable, to place these at the appropriate level, and to identify requisite conditions for the objectives. Since 1950, developmental psychologists, spurred on by Piaget's writings, have uncovered a wealth of information very useful for science teachers. For example, many secondary school students are not yet capable of abstract formal thinking and need concrete experiences that will foster the development of formal thought. Applying the concrete-formal notion to an examination of your objectives should allow you to select the most appropriate objectives and to identify necessary pre-conditions. What the student knows and can do is the most important determiner of what the student will learn on any given day (Novak, 1977). Hence, it becomes absolutely essential for high school teachers to examine the curriculum of the middle or junior high school. If their preceding science experience has been descriptive textbook science, the students' only thinking experiences will have been memorizing conclusions. To develop the formal reasoning skills needed to understand science the student will need to be provided sequenced practice - beginning with concrete and leading progressively toward problems involving abstract reasoning (Case 1979; Elkind, 1981). Without this one-step-at-a-time practice many students will continue to learn by rote. An excellent explication of developmental steps and instruction is provided by Case in the 1980 AETS Yearbook (Lawson, 1979).

The suggestion of philosophy as a second screen is based on Tyler's conviction that each course should contribute to the development of society. Science has most frequently been taught for the sake of science. Even the human science biology has a marginal emphasis on biosocial goals (Hurd, 1981). However, it appears as if new curricula giving appropriate emphasis to science's role in society will soon be developed (Harms & Yeager, 1981).

On the preceding pages, Tyler's suggested procedure for selecting curriculum objectives was described. It is obvious that changes in the secondary school science curriculum and in science teaching practice are needed. Persons studying change indicate that attempting to change practices of secondary school teachers has been most successful when the teachers are involved with creating the change, not simply implementing change. It appears that when teachers, themselves, do no synthesize the goals and objectives they typically do not become committed to them (Mann, 1976). On the pages that follow we will continue to rely on Tyler as we think about an individual change strategy.

## CHANGE

It is my firm belief that many individual attempts to change are unsuccessful because the individual attempts to change too much too fast. Each of us knows a teacher who seems to become a little more effective each year. We also know a teacher who doesn't seem to change but continues on year after year doing the same thing and becoming increasingly more bored and boring. Which teacher are you? If you are that bored/boring teacher were you always that way? Probably not! But what happened? And what can you do?

There are undoubtedly as many explanations for what is called teacher burnout as there are teachers who appear to be burned out. However, there is a single cause that is at least partially responsible for every case of burnout. That single cause is Failure. Failure to obtain a desired response from a student, the principal, a parent, or a colleague. Failure to obtain supplies and equipment. Failure to get an acceptable pay increase. Some teachers continue to pursue success, but others slowly begin to adopt strategies that will help them avoid failure. That is, they stop taking risks, don't try new methods, and revert to using only those teaching strategies that seem to be the safest. We teachers, like our students, obey Thorndike's Law of Effect. We repeat those activities that are successful. Teachers who continue to become more effective have continued success. Thus, the question becomes one of determining how teachers can attain more success, and Tyler offers a solutions. Tyler suggests:

1. Identifying goals
2. Stating objectives
3. Selecting strategies that provide practice
4. Evaluate

Tyler, like Bloom, focused attention on developing curriculum for instruction. However, the same procedures can be systematically applied to teaching.

Identifying the goal(s) is often the most important step. If you know where you are going (the goal) the probability you will get there is enhanced. There are goals and there are goals. Some will be easy to attain, and selecting a realistically attainable goal is essential. To illustrate this point permit me to repeat a story I once heard a prominent U. S. senator tell about himself. He was talking about his long and very successful senate career. When elected, he said, he moved into the senate with the goal of attempting to save the world. As an experienced senator, he revised his objective, settling on simply saving the U.S.A. and finally in the twilight of his successful career he once again adjusted his goal and claimed he would view his life successful if he could just "Save the Indiana Dunes." Many teachers launch their careers thinking in parallel terms but, unlike the senator who throughout his career identified subordinate objectives and pursued their attainment enthusiastically, teachers often try to achieve the single big objective. When they fail, they adopt survival tactics which control students but do not stimulate them to learn. Identifying a goal is a rational and necessary first step. However, the second step must be to identify the realistically attainable subobjective. Excellent teaching is a complex activity. It is composed of many definable skills artistically combined. You cannot expect to artistically combine something you do not have. Mastering all the skills instantly is impossible. You must proceed, one step at a time. Simply wanting to be a good teacher is not enough. As basketball coach Robert Knight points out, many players have a will to win but the successful are those who have the will to prepare to win! That means planning and practice! While you will occasionally hear experienced teachers brag that they never plan lessons, you will discover that the really good teachers spend a fair amount of time designing new teaching aids and planning their lessons. You may also discover that even the very good teachers who have planned carefully will have "bad" days, and that too, is reality!

One step at a time is my recommendation but only after you identify that first step. To do this you might collect student evaluations, listen to a tape recording, or view a videotape of yourself. One suggestion is that you identify the "squeakiest wheel" and work on it! However, the best advice may be to remember that you want to learn how to teach more effectively. You are the student and, as Tyler points out, interest may be the most appropriate starting point. Hence, begin by working on developing the skill that interests you most. As you successfully master that skill, you will discover that you will develop interests in working on another skill.

An acceptable definition of good teaching is that good teaching is the ability to successfully implement a variety of teaching strategies; e.g., laboratory, lecture-discussion, demonstration, etc. This is an acceptable definition because it is known that the students of teachers who use a greater variety of teaching strategies learn more (Rosenshine and Furst, 1971).

Teaching is such a complex activity that almost any skill you can mention has prerequisite skills. For example, selecting the correct strategy is certainly a prerequisite to implementing a strategy. The strategy selection process should be initiated by thinking about all the different ways that could be used to teach a given skill or subject. Once a full variety of strategies has been identified, the five general principles suggested by Tyler (195=49) can be used as selection criteria. Rephrased these are:

1. Practice must be consistent with the behavior implied in the objective.

2. The practice should be satisfying to the student.

3. The reactions desired should be achievable by the student.

4. Alternative experience should be provided students.

5. Outcomes, other than those expressed in the objective, should be attained by the students.

Applying Tyler's principles systematically will help you select a strategy, and to some extent they should help you implement a strategy. However; selecting has as its prerequisite knowing the choices, which today are referred to as teaching models. Much of the literature that defines (describes) teaching models in terms of specific observable teaching behaviors (skills) is recent (Joyce and Weil, 1972). Viewing teaching strategies as models with definable elements allows one to identify specific skills and skill sequences that can be developed systematically, one step at a time.

It is essential that you examine current literature which provides specific descriptions of teaching behaviors of a model because many descriptions that exist in the literature are less than helpful. For example, what is meant by the term Laboratory Teaching Strategy? If you examine common teaching practice, you might conclude that it means announcing to your students that tomorrow they will do laboratory exercise 7 on page 42 of their laboratory book. Furthermore, they should read the laboratory book before they come to class. Students, for the most part, ignore the command to read ahead because they have learned that the lab manual is a cook book, that doesn't need prior reading. When the laboratory strategy is defined and implemented as described, students find experiments boring.

There are at least four families of laboratory teaching models that may be classified as 1) confirmation laboratories, 2) directed inquiry laboratories, 3) guided laboratories, and 4) open inquiry laboratories. These models can be arranged on a continuum as illustrated in Fig. 2.

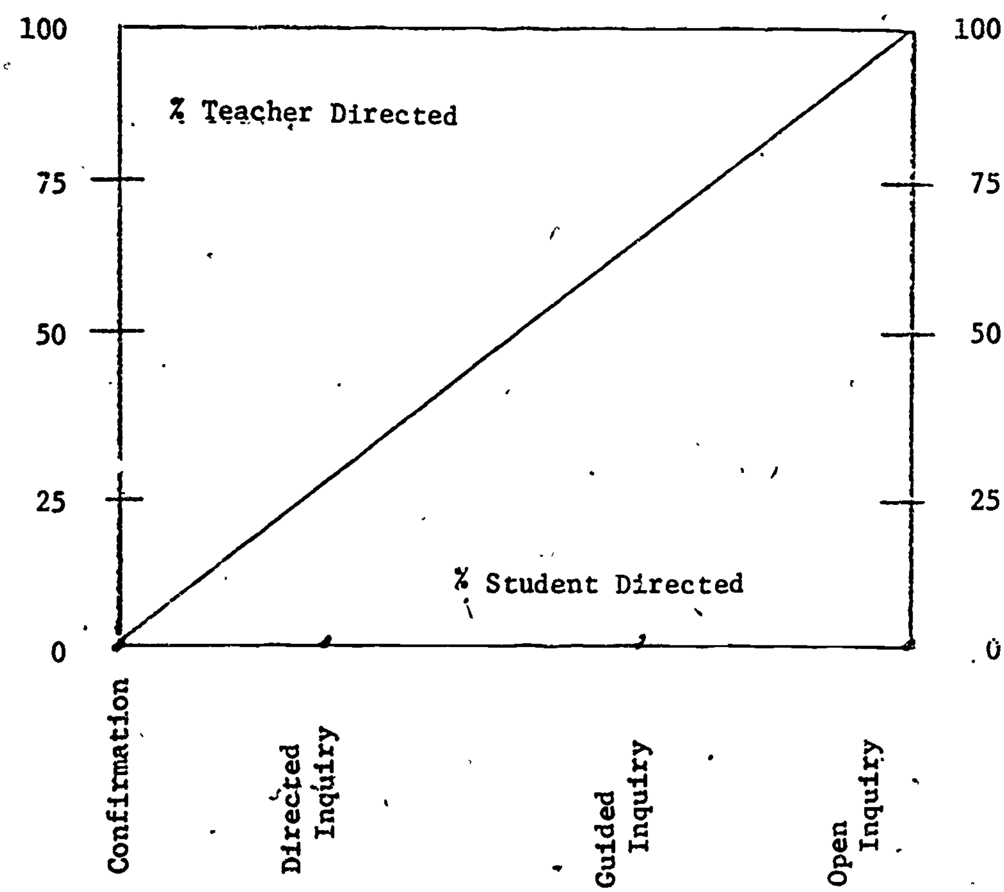


Figure 2

TYPES OF LABORATORIES

Each type of laboratory calls for different teacher and student behaviors. Confirmation laboratories are teacher directed, while the teacher implementing an open laboratory must behave more like a research colleague. As students move along the continuum from confirmation to open, they assume more responsibility. The teacher's responsibility is not diminished, but it is different. You can see from this illustration that it is suggested that students may learn how to inquire, one step at a time. Teachers similarly are advised that they too can profit by considering themselves to be developing and capable of moving along a continuum progressively, learning more teaching strategies, and becoming increasingly more effective as teachers, one step at a time.

That teaching is a complex activity that can be developed one step at a time is important to remember. Very few beginning teachers are outstanding, and, as Professor Herron states in his chapter, most teachers teach about half as well as they know how to teach. Setting a goal of mastering a variety of teaching models will be useful but only if you employ an economical means of evaluating your teaching. It is probably true that most teachers are too busy planning to teach and teaching to evaluate their effectiveness. In some schools friendly administrators will assume the responsibility of teacher evaluation and provide valuable suggestions. In other schools teachers regularly visit each other's classes and exchange ideas on improving teaching practice. However, all schools have a virtually untapped source of potential evaluation expertise - the student.

I am not suggesting that students be taught complex interaction analysis schemes. Generally speaking, simple evaluation devices can be invented by the teacher, on the spot, taught to a student in a few minutes, and used to collect data for later interpretation. For example, assume you are interested in the kinds of questions you are asking students. Bloom's six categories (Bloom, 1956) or Guilford's four categories (Guilford, 1968) might take a student too long to learn. However, in five minutes you could probably teach a student how to discriminate among memory, narrow, and broad questions and set that student loose collecting data. Students can, and will, enjoy collecting data for you. Teachers who have so involved students indicate that students not only obtain useful data but that they also tend to gain a sympathetic understanding of the teacher's role and become more cooperative. Ideally, you will be able to involve students during one of their free periods. If your school doesn't have free periods, ask a student in your class to collect the data. Which student? Remember your solution to the disappearing materials problem? You put your number one suspect in charge of inventory. If you put your worst discipline problems in charge of teacher evaluation you may not only succeed in keeping them from interrupting your teaching, you may signficantly change their behavior, and their interest. And that, as Tyler notes, is the point of departure.

## SUMMARY

Not all teachers burn out! Many seem to improve through their careers because they continue to make small changes that add up to big changes. They continue to enjoy teaching because teaching continues to be a challenge. If you study these teachers you will learn that they have spend their careers asking, Where am I going? How shall I get there? How will I know I've arrived? as Tyler suggested. Furthermore, most of them did it one step at a time.

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# ACHIEVING SCIENTIFIC LITERACY THROUGH CONTINUING EDUCATION

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One does not progress far in the study of science before encountering the concept of parsimony. Webster's Dictionary (1970) defines parsimony as economy in the use of a means to an end. In science the meaning of parsimony is enlarged to include the notion of elegance in simplicity. Given, for example, two equally well constructed theoretical explanations, scientists view the more economical interpretation as the more elegant. Simplicity and its associated elegance are valued in the realm of science no doubt because scientists desire that theories reflect the simplicity and elegance found in nature.

However, education is very complex compared to science. Few theoretical models capable of providing clear, far-reaching explanations of educational problems have yet to emerge, although the development of powerful theories is now underway and eagerly awaited by the science education community.

Nearly 20 years ago science education experienced a period of major development. Professor Yager has discussed in Chapter 2 the nature of the Sputnik crisis and the curriculum development that resulted. His analysis has provided an excellent historical perspective to the current emergency in science education. And the science education community must look carefully into the present emergency, because its implications are more important to science curricula and the citizens of this country than was the Sputnik crisis.

Ralph Tyler's (1949) rationale for analyzing and interpreting curriculum and instruction is a valuable aid for such an endeavor. Although Tyler's rationale is now 33 years old, it remains important in the study of curriculum and instruction because it possesses economy and elegance. We can think of Tyler's rationale as a looking glass or lens, through which curricula can be analyzed. Presently, Tyler's rationale provides a clear picture of the dimensions of the crisis. It does so by posing four fundamental questions:

1. What educational purposes should the school seek to attain?

2. How can learning experiences be selected which are likely to attain these objectives?

* In alphabetical order. Each author made an equal contribution to the writing, editing, and revising of the chapter.

3. How can learning experiences be effectively organized?

4. How can we determine whether these purposes are being attained? (1949, p. 1)

Although the four questions are economically and elegantly posed, there is a danger. Parsimonious questions do not necessarily yield parsimonious answers. Tyler's rationale provides a clear view of the crisis, but offers no easy solution to the problem because many factors affect curriculum. Each author in this volume has looked at the impending emergency through the lens of Tyler's rationale, chosen some aspect, described and analyzed it, then suggested a course of action based upon it.

Others workers have also undertaken such analyses. In the message of Hufstedler and Langenberg to the President of the United States entitled Science and Engineering Education for the 1980's and Beyond (1980), they state:

> The Nation's elementary and secondary educational system has traditionally been regarded as an essential vehicle for achieving two broadly defined sets of social goals, consistent with the ideal of universal education:
>
> * To provide to all citizens knowledge and training consistent with their individual abilities, and opportunity for the fullest possible individual growth and development to allow them to function effectively in a variety of pursuits; and
>
> * To translate, into practice, Thomas Jefferson's familiar dictum than an enlightened citizenry is the only safe repository of the ultimate processes of society.
>
> The public school system . . . . is being called upon to translate the broad goals noted above into contemporary terms for science and mathematics by carrying out the following tasks:
>
> * Generate a sufficiently large pool of people, adequately educated in science and mathematics, from which may be drawn: (a) the relatively few talented and committed students who will go on to become professional scientists and engineers; (b) future non science professionals such as lawyers, journalists, and managers who will require considerable levels of sophistication in scientific and technological matters; and (c) future technicians and members of the skilled work force who will pursue their operations in an increasingly technological economy.
>
> * Provide all students with sufficient access to education in science and mathematics to allow them to pursue these different career options.
>
> * Equip all students with a sufficient understanding of the concepts and processes of science and technology and the

relationships among science, technology, and society so that they can function as informed citizens in our democracy. (p. 45)

Hufstedler, the former Secretary of Education, and Langenberg, the former Acting Director of the National Science Foundation, are saying what Dr. Rubba has discussed in detail earlier in this volume. The answer to Tyler's first question is to develop a scientifically literate citizenry.

## DIRECTIONS FOR ACTION

We noted earlier that a multi-faceted science curriculum causes curriculum planning to be a complicated process. A model that represents a multi-faceted curriculum can form a framework for a course of action. Such a model is discussed in Professor Andersen's chapter in this volume. His holistic curriculum model (Andersen, 1978) clearly illustrates the varied nature of science curriculum in the 80's. Further, it is based upon Tyler's (1949) rationale. The integrated science curriculum that Andersen discusses must become a reality in the 1980's if science education is to survive the present crisis.

Andersen (1978) stressed a crucial point in his delineation of the holistic model that was originally made by Tyler in Basic Principles of Curriculum and Instruction: Interest is the point of departure. Whereas Andersen argued that students may begin studying science at a point interesting to them and then move toward goals designated by science teachers, we argue that science teachers often begin teaching science at their own points of interest, but that they need to include the aspects of science that interest most students. And, given the nature of secondary science teacher preparation, beginning science teachers' interests are most likely in the empirical and central areas of the holistic model. Yet students' points of interest are scattered throughout all facets.

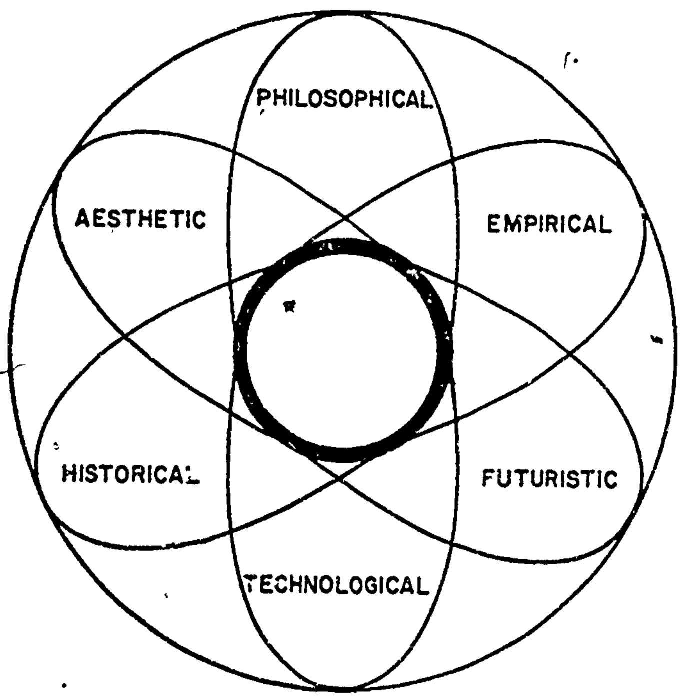


Figure 1. Andersen's Holistic Science Curriculum Model

No wonder many new science teachers fail to survive the first few years. The science they know and love is not the science that interests many of their students.

An inspection of preservice secondary science teacher preparation and continuing teacher education will clarify the point. Let's consider preservice science teacher preparation first.

A science major in a secondary teacher education program needs approximately 125 semester hours to graduate. About 40 semester hours are taken up by the major content discipline, and another 20-25 hours in a minor area. The remaining 60-65 semsester hours are allotted to the teacher education sequence and general institutional requirements. The major discipline and the teacher education sequence are in the areas of interest.

Science courses in the major discipline (and the minor, too) generally reflect the empirical and central areas of Andersen's holistic model. This is because teacher education majors and science majors preparing for medicine, dentistry, and other science careers generally take the same courses. Thus, recent teacher education graduates should feel comfortable with their knowledge of science. Our view is supported by an AAAS report on the implications of three recent NSF-supported studies on the state of precollege science education (Smith, 1979). The report notes that, although many criticisms have been made of teacher preparation programs, the fact is that almost no major teacher preparation institution would graduate and recommend, for example, a biology student for certification as a teacher without a sound grounding in botany, zoology, and physiology, with required courses in genetics, organic and inorganic chemistry, microbiology, etc. This is true generally for students in all sciences.

Thus, new., certified science teachers often encounter a mismatch between their interests and those of their students. The empirical and central aspects of science, while interesting and challenging to teachers, are deemed irrelevant by many students. A 1977 NAEP assessment of attitudes of 9-, 13- and 17-year-old students about their science courses (Crane, 1978) revealed that three in four felt that their science courses were useful. But only slightly more than one-half believed that what they learned in science would be of use in the future. Further, two out of three students in the 13 year-old group were not planning to enroll in more science or were undecided. Twenty-one percent of the 13-year-olds and thirty-one percent of the 17-year-olds found science boring. However, three of four felt that science knowledge would eventually be of value.

The mismatch between teacher and student interest extends into the textbook. In their report to the President, Hufstedler and Langenberg wrote:

> Federal sponsored curriculum development programs were an important strategy for improving science and mathematics teaching in the post-Sputnik salutary effect. Today there is a need for similar programs, but the target group is different. While programs of the 1950's and 1960's were aimed at developing textbooks for future science and engineering careers. There is a great mismatch between the content of secondary school science and mathematics courses and the needs and interests of students for whom these courses will constitute their entire formal scientific education. With few

exceptions, these courses are not directed toward personal or societal problems involving science and technology; nor do they offer any insight into what engineers and scientists do; nor do they have vocational relevance except for the chosen few.

New curricula could provide students with a better basis for understanding and dealing with the science and technology they encounter as citizens, workers, and private individuals. But stimulating interest in science and technology, they can also motivate students to take science and mathematics courses beyond tenth grade, thereby preserving their options to enter science and engineering courses. The development of new curriculum materials that speak to the needs and interests of the broad spectrum of the students would incorporate the last 20 years of experience in achieving constructive change in our schools (p. 50).

To a lesser extent the recent graduate is placed in the position of a teacher who is assigned "out of area." The futuristic, historical, aesthetic, and philosophical areas of science that often interest students have been largely ignored during teacher preparation. Smith (1979) notes that misassignment, not lack of preparation, is one of the most grievous problems in American education. In fact, only 27 percent of the secondary science teachers studied in the Research Triangle Institute Study (Weiss, 1978) had teaching assignments restricted to science.

One justifiable criticism of preservice teacher education, lack of connection with the real world, is already being dealt with in teacher education institutions. The separation of the real world from the ivory tower is exemplified by the fact that until recently initial encounters between preservice teachers and student often occurred during the student teaching experience. The re-establishment of an early, continuous connection between university teacher preparation and the schools came with state mandates for pre-student teaching clinical experiences. Thus, teacher education students have an opportunity for continuous integration of practical field experience with the theoretical, interpretative, and methodological experiences of teacher preparation.

Preservice science teacher preparation needs to expand to fit state needs for the 1980's and beyond, and must include science courses whose foci are in the historical, aesthetic, technological, philosophical, and futuristic dimension of Andersen's model; and it must firm up the integration between theory, methodology, and the field prior to the student teaching experience.

Yet we may have set an impossible task for ourselves with respect to preservice teacher preparation. Given the nature of science (change), several years of preparation beyond the baccalaureate level might be needed. We must be reasonable. Part of a solution to this problem is the recognition that teachers, like their professional colleagues in the legal, medical, and dental professions, need to stay abreast of recent developments in the field.

Yet after graduation, life frequently becomes more complex as science teachers, like other adults, assume the added responsibilities of adult daily life. This fact is made more significant by what Roger Gould (1978), a psychiatrist at the University of California-Los Angeles, calls the "century of the adult." Indeed, the latest census figures indicate that the average age is now 30 and expected to increase.

Continuing education has become the vehicle to meet the challenge of this demographic shift and its effect on the needs of education. It forms the bridge between the university and layperson and meets a variety of needs particularly in science where there is a greater gap than in other fields. It helps professionals, in our case science teachers, to earn credentials, to advance, or to change careers; offers personal growth to individuals through cultural and intellectual stimulation; assists in preparing people for life alternatives; and prepares citizens to meet their civic responsiblities. As we become a learning society, however;

> continuing education for adults beyond age 25 holds somewhat different problems and opportunities. Education must be convenient, and it must be integrated with the pursuit of living, family life, careers, leisure time activities, and the necessities imposed by active citizenship careers (The Learning Society, 1972, p. 5)

The "graying of the campus," as it has been called, has caused an important shift on the part of faculty and administrators in instructional methodology, course content, and sensitivity to student needs. Adult students come with different expectations, values, experiences, and maturity than those in the 18-21 age category. Figures 2 and 3 indicate some of the characteristics that differentiate the traditional college student from the new majority (Kurtz et al., 1975). Whether in a credit or noncredit course, adults are more demanding of the instructor. As voluntary learners they seek flexibility, are less hesitant to ask questions, are more interested in specific problems and skills and how they may be applied immediately, are stimulated by person-to-person interaction, are motivated to relate personal experience to the discussion, and learn organically--that is, they learn best when they relate new knowledge to what is already known.

Adults have an increasing sensitivity to their changing society, brought about, in part, by the technological advances of the modern are. When viewed in relationship to the large number of adults returning to school, the variety of available opportunities, and the adult learning style, this sensitivity has a particular relevance for the advancement of scientific literacy. Professor Yager discusses the transitory state of science education in An earlier Chapter I of the present volume. What seems to emerge as an important goal is the relationship between science and society; that is, applying scientific knowledge to improve society. An important impetus for the growth of continuing education enrollments is the technological revolution--the need to stay informed in an ever-changing world. The recent success of the space shuttle, the attempt to locate the Titantic using sophisticated radar/video techniques, and advances in computer technology are among events that have heightened our awareness of science.

Robert Glover (1979) in The Future: Alternative Scenarios of American Society (1980-2000) discussed several issues, among them science and technology. Not surprisingly, his survey indicated that Americans will depend more and more on computers and other devices in areas such as information, recreation, and maintaining family records. The changes in our communication systems (e.g., the use of lasers) will create even more dramatic alternatives in the way we live. As important as these developments in technology are, they do not necessarily create a more scientifically literate populace. New initiatives in science education are needed if a purpose of science education is the development of human, rational, inquiring individuals who possess basic

## DICHOTOMY BETWEEN THE TRADITIONAL STUDENT AND THE NEW MAJORITY

| | Traditional Student | | New Majority |
|---|---|---|---|
| 1. | Continuing in school | 1. | Returning to school |
| 2. | Learning history strongly influenced by formal education | 2. | Learning history strongly influenced by informal education |
| 3. | Familiar with educational routine | 3. | Unfamiliar educational routine and expectations |
| 4. | Primary time commitment to school--full time student | 4. | Major time commitment to family and job--part-time student |
| 5. | Adequate communication and study skills | 5. | Frequent deficiencies in study and communication skills |
| 6. | Minimal work experinece | 6. | Considerable relevant work experience |
| 7. | Micro frame of reference for a more orderly input of new | 7. | Macro frame of reference which has a dual (+) effect |
| 8. | Frequently no clear vocational goal | 8. | Frequently clear vocational goals, but not necessarily related to education program |
| 9. | Educational goal is to receive a baccalaureate degree at minimum | 9. | Educational goal may be to receive a degree, but also includes some form of certification; or lesser degree |
| 10. | Speed of performance and peer competitiveness affects learning activities | 10. | Concept mastery and accuracy of performance more important than competition - frequently viewed as threatening |
| 11. | Clear idea of how he compares with academic performance of fellow students. | 11. | No accurate basis on which to judge his academic potential |

Figure 2

## THE CHILD DEVELOPMENT STUDENT

| Traditional Student | New Majority |
|---|---|
| 1. Four-year BA program | 1. Career Ladder |
| 2. Lower and upper division course sequence | 2. Integration of lower and upper division courses |
| 3. Fairly clear understanding of academic readiness | 3. Aptitude testing to clarify goals and expectations |
| 4. Adequate test-taking behaviors | 4. Test-taking behaviors are rusty |
| 5. Fulfill full-time residency requirement | 5. Distribute learning over many years |
| 6. Adequate readiness skills | 6. Assessment and training in readiness skills |
| 7. Credit by examination to assess formal learning | 7. Credit by "examination" to assess informal learning |
| 8. Compartmentalized theory and professional courses | 8. Integrated theory and methods courses |

Figure 3

skills such as classification and observation; who can formulate observations and draw inferences; who can perceive spatial relationships, and thus, cope with both societal and environmental change. Continuing science education must be directed as an expansion of the science teacher's own scientific literacy into the futuristic, technological, historical, aesthetic, and philosophical domains of scientific literacy. In addition, teachers must study more about the setting in which they work, and all the participants in that setting.

Earlier in this volume Herron discussed several social and political factors that affect the curriculum. His words, injecting the cold light of realism, extend a challenge to the science education community to improve the curriculum and describe the difficult nature of the task. Joyce (1981), writing about staff development in the 1981 Yearbook of the Association for Supervision and Curriculum Development, provides further support for Herron's argument:

> Changes that require new organization are much more difficult to implement than those that fit comfortably into the normative structure of organizations. Community support and joint 'ownership' of innovations are essential for implementation.
>
> ...substantial, continuous staff development is essential to the improvement of schooling and, equally important, to the development of the capability for the continuous renewal of education. A static school is a dying school. Staff development is one essential ingredient of a lively dynamic school that improves through the release of a self-feeding energy born of the quest for itself understanding about how creative teaching and learning can best take place. (Joyce, 1981, p. 117)

Concerning the goals for staff development, Joyce writes:

> The primary task in staff development is to develop a professional, growth-oriented ecology in all schools. The purposes are three:
>
> 1. To enrich the lives of teachers and school administrators so that they continuously expand their general education, their emotional range, and their understanding of children.
>
> 2. To generate continuous efforts to improve schools, school faculties, administrators, and community members need to work together to make their schools better and acquire the knowledge and skills necessary to bring those improvements into existence.
>
> 3. To create conditions which enable professional skill development to be continuous. Every teacher and administrator needs to be a student of learning and teaching and to engage in a continuous process of experimentation with their behavior and that of their students. Each education professional needs to study alternative approaches to schooling and teaching, to select ones which will expand their

capabilities and to acquire the understanding and skills necessary to make fresh alternatives a part of their ongoing repertoire of professional competence. (Joyce, 1981, p. 118)*

Let us examine two examples of ongoing professional development within the context of Herron's realism and Joyce's goals. The first example describes a successful continuing education program in the Rock Island Public School District, Rock Island, Illinois. Professor Donald Troyer, a science educator at Western Illinois University, has directed the Rock Island program in cooperation with a school district coordinator. The program involves science education faculty, preservice teachers, and faculty and administrators in the Rock Island Public School District. Staff development occurs during the school day, and preservice teachers, under legal supervision and guidance, replace faculty in the classroom. Teachers then attend staff development programs.

Since its inception in 1973, the program has survived distri and university budget cuts. The reasons are twofold. First, the cost the program is minimal to all involved. Second, the school district teachers and administrators supported it because they perceive the program to be successful. Continuous input, participation, and review by faculty and administration at the elementary, middle, and secondary levels has helped to achieve the joint ownership deemed crucial by Joyce. A participation waiting list now exists.

The second example involves information-sharing among teachers in different schools. In the Chicago metropolitan area, two major science discipline teacher groups (physics and chemistry) are very active. The groups are informally organized, and teachers generally attend meetings one evening each month at a designated school. The purpose is to share ideas, techniques, and developments, and occasionally to hear a guest. Attendance at such meetings usually consists of 25-35 secondary science teachers. Although most of the teachers are active in state and local professional societies, these local meetings are completely independent of such groups, and the round trip distance to the meeting frequently exceeds 80 miles through metropolitan rush-hour traffic one way. The physics group has been meeting for ten years. Science teachers in rural areas frequently deplore lack of interaction with colleagues. We suspect, however, that a 40-50 mile radius about a rural point should include enough science teachers to make such informal sharing a profitable venture at a minimal cost to participants.

Unfortunately, many teachers fail to accept the responsibility to stay abreast of developments. Therefore, professional development on a long-term basis must become a part of teacher certification. Few states currently have mandated such measures. However, some local school districts have accepted the responsiblity for mandating the professional development of their new faculty. Even where locally mandated, however, support for such professional development is often nil.

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During the next few years the politics and fiscal climate in Washington, D.C., will place a major share of the responsibility for continuing education on the state, local, and individual level. While the science education community argues its position in the federal political area, it must also organize its continuing education support better at the state and local level, and the support must include multiple options at these levels. Seminars, institutes, university/college courses, workshops, drive-in conferences, and science teaching centers should all be part of the continuing education effort.

Classes in informal settings represent another avenue for professional development. In Bloomington, Indiana, a program known as Hilltop has been in existence for a number of years. The participants are young children, and the program involves their planting a vegetable garden. Under the supervision of a retired faculty member from the Indiana University Biology Department, the program has taught the children more than the act of planting a seed. An understanding of and appreciation for the ecosystem has not only enhanced their skills as gardeners but also has changed their attitudes toward living things such as weeds, bugs, and the like.

The principles involved in this program are as applicable to adults as they are to children. College professors and practicing scientists can all participate in the process of educating society. Programs ranging from understanding our solar system to knowing what lies below the ocean can be offered successfully to adults. One of the most often overlooked community resources that can have a substantial impact on scientific literacy are elementary and secondary school science teachers. Their knowledge and skills are particularly well-suited to educating society.

Facilities already exist that can serve as locations for adult programs in science education. High school laboratories frequently go unused in the afternoons and on weekends. The use of special museums for science and technology, aquariums, oceanographic research centers, observatories, and industrial research centers also can become the basis for this new direction in science education and can add a measure of enrichment heretofore unrealized. The attitude of the public toward the full utilization of all these facilities has never been more positive, aided in large measure by the high cost of energy.

If the field of science education is to move in new directions, strong consideration should be given to altering certification requirements. Associations such as AETS are in a position to take a lead in suggesting change. Rather than requiring a credit course for certification, why not consider a noncredit program designed specifically to meet the teacher's need? These short-term programs may be beneficial in many ways, such as assisting a high school science teacher to develop new skills in dealing with adults, aiding in the creation of a noncredit course to offer adults, or providing an opportunity to discover new uses for graphics and other aids in teaching the adult.

Several years ago the Mott Foundation funded a number of community education programs, usually located in a public school system. Theoretically, this program was to serve as an agent among local two or four-year colleges, community organizations, and the public schools to help match existing resources with identified needs. If no resources were available, the community education office became a provider by securing the necessary resources to meet the need. This may be an area to explore in order to have a more scientifically literate society.

The final area of discussion concerns the issues addressed by each chapter author in the present volume. Tyler's rationale, described by Rubin, represents a most valuable tool for thinking about curriculum. But it is not the only such model. Science teachers need to become more aware of curriculum models. The current emergency in science education, delineated by Yager, certainly requires further study. Learning, teaching, and problem-solving styles and student motivation, addressed by Berger and Bersenberz, respectively, are important issues for professional development. We must learn more about the social and political factors described by Herron that affect the curriculum if we are to be effective in the political arena. Andersen's curriculum model must be tested for suitability, and his suggestions for change implemented by teachers. We must learn more about the nature of scientific literacy described by Rubba. Lastly, we must continue our education throughout our careers. This volume represents only the beginning. Each author provides references for further study. They should be used.

## SUMMARY

We again note that the science education community is part of the massive political arena in which education occurs. Where the education of our students and the continuing education of our teachers is concerned, we cannot take the ostrich approach. It is disheartening to see the only interaction between faculty and administrative staff in many school districts taking place at the professional negotiations table. Such interaction has unfortunately become adversarial in nature, when both groups should be working together in the local, state, and federal political arenas. We in science education are, in large part, responsible for the present emergency. We have a democratic form of government in which most of the decision makers are not scientifically literate. We in science education have concetrated on the preparation of future scientists and ignored the majority of our students to the extent that our relevance is being questioned. We have continued, as Tyler points out, to ask the question: "What should be elementary instruction for students who are later to carry on much more advanced work in the field?" Instead, we must set about answering the question that Tyler described as the one that subject matter specialists should be asked: "What can your subject contribute to the education of young people who are not going to be specialists in your field; what can your subject contribute to the layman, the garden variety of citizen?" (Tyler, 1949, p. 26).

We already know that the goal is a scientifically literate citizenry. Its attainment involves commitment to long-term continuing education for science teachers, a wider scope of instruction for students, and working together (teachers, administrators, academics) in the political areas. As Anderson so economically stated in his chapter of this volume, we must set forth, one step at a time, as we cannot afford to procrastinate.

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PART III

FROM THE FIRING LINE...

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One might assume that this Yearbook consitutes an ode to Ralph Tyler, and well it might. To those of us who are actually responsible for the development of curriculum guides, his model is an invaluable tool. The several chapters in this book describe very accurately the many variables and problems which impact on science curriculum and instruction. The Tyler model offers a systematic approach which can be used to chart a path through what seems to be an educational morass.

The reactions offered here come from the vantage point of one who supervises a science program in a large urban school district, with a diverse population, dwindling enrollments, and a shrinking budget. Teachers are unionized, administrators feel forced to jockey from position, and governmental and political pressures are fierce in intensity. The community is largely dissatisfied with the achievement levels of the students. This is to say that the situation is not atypical in this time of societal turmoil. How can the AETS yearbook can be of help to practioners? Some suggestions follow.

## A Tylerian Approach to Science Curricula

The Tylerian approach to curriculum building offers a strategy to be used to get the needed work accomplished. Louis Rubin states that this model makes no precise recommendations regrading content, and that it is vulnerable to judgmental mistakes, while being independent of political consideration. It can be argued that such statements are beside the point. It is not the function of a model for curriculum development to determine the content, philosophy, or student goals. These considerations are best dealt with by the curriculum developers who know the nature of the student clientele and the community from which they come.

The Tyler model is useful to curriculum developers, but it is not sufficient when used alone. Other models which provide a structure for working out the details of an effective curriculum must be integrated with it. Questions about how schools shall be organized, student progress reported, and criteria for promotion must also be addressed.

Practical experience will show that effective and efficient curriculum can be developed and delivered provided (1) that enough time is allowed (at least five years, preferably seven) and (2) that the community is demanding improvement and willing to support the whole model, not just pieces and parts. Everyone involved must want to "do something" desperately. Curriculum developers and their supervisors must be aware of and sensitive to the needs of students, and why it is not longer feasible (if it ever was) to base curriculum decisions on textbooks and other factors external to the students and the situations in which they find themselves.

It is necessary to "flesh out" Tyler's model to encompass the variables needed to develop an ongoing recycling method for developing curriculum and then implementing that curriculum. Until the learning is delivered successfully to students, and teachers realize the satisfactions which come from causing students to learn, there is no measurable profit from the endeavor. (Sardonic Note: When there is no money available for textbooks, it becomes much easier to put curriculum guides to work.)

## The Current Situation in Science Education

The account of Project Synthesis gives some idea of what a monumental task it is to assess the strengths and weaknesses of science education and to trace the roots of the problems we are now facing. The value of the work being done cannot be overestimated. To reap the profit from this work, the science education community must somehow save the report from suffering the same fate as the national curricula suffered, namely little adoption and use. Our task is to profit from the findings by doing the extra work necessary to put science education into the context of schooling as it exists today.

## Scientific Literacy: The Decision Is Ours

The decisions about what the instructional program shall include are indeed in the hands of teachers and curriculum developers. Although publishers have largely determined the curriculum in the past, they have done so because we have allowed it to happen.

As more and more curriculum is developed at the local level, and communities continue to demand that students acquire competencies which they need for present day living, we will find that appropriate instructional materials will be forthcoming, as the demand increases.

Science educators may well have to rethink their own values and priorities. Shall pre-service teachers be encouraged to think of themselves as biology, chemistry, or physics teachers? Maybe the general science teacher, who feels capable of teaching the science processes through studies of energy, resource management, pollution control, and other such themes will be in more demand. As enrollments dwindle more and more teachers will be asked to teach "out of their field" for students who are not in the market for college preparation in the sciences. Local school supervisors are even now facing up to the necessity of providing continuing education (we call it ongoing in-service education) for seasoned faculty members who are being asked to teach scientific literacy or "life skills" topics.

The key concepts listed in this chapter are very likely to become more important as curriculum topics because we will continue the effort to educate all students to meet the demands and responsibilities being placed on them as they become functioning adults.

If the trend toward student-centered curriculum continues, we may soon be expected, as science teachers, to work with mathematics, social studies, and English teachers to develop interdisciplinary courses based on "student competency" goals which lead to literacy. This author can say, from first-hand experience, that this is no easy position to be in. Changing one's personal frame of reference from "content-centered" to "student-centered" curriculum requires painstaking thought and effort. Having the powers of decision-making because of having ownership of the curriculum is to inherit a huge responsiblity.

## But -- It Doesn't Work For Me

When this title phrase is uttered by a teacher it is often hard to interpret exactly what is being said. Does it mean that no feelings of satisfaction are experienced by the teacher at the end of the day, or is it a reflection of the fact that the curriculum being taught doesn't cause students to behave properly during class sessions? Maybe the students are not showing any evidence of becoming more informed about the subject.

Perhaps the mistake being made is in expecting any curriculum to "work" in and of itself. One does not expect a road map to do the traveling which is made possible by its use. Curriculum guides are a tool, and teachers who focus on the curriculum instead of on the students who are to do the learning are probably doomed to a feeling that it "doesn't work" for them.

A given curriculum does specify what is to be learned, and it ideally identifies ways in which the quality and quantity of what has been learned can be assessed. It will also make suggestions as to how the learning can be accomplished. To imply that using it verbatim will automatically bring results in the hands of every teacher in fraudulent. Even to claim that it will be effective and efficient in the hands of most teachers requires that extensive field testing for validity and reliability be conducted. This is costly and is not often done.

Carl Berger has identified an important step for the future. Teachers do need to learn more about how to detect and respond to different teaching syles and learning styles. Problem-solving style research does sound promising. As the users are helped to become more adept at using curriculum as the tool which it is, curriculum will more often "work for me."

## How To Make It Fun For Kids

Motivating students to learn, as Dr. Beisenherz points out, has been a perennial problem growing worse in response to the societal changes which have occurred since World War II. He and others have correctly stated that enthusiastic teachers encourage enthusiasm for learning in students.

Teacher "burnout" is becoming more prevalent for a myriad of reasons too complex to discuss here. This is a problem that science educators could well address with some overt action immediately, even before we finish discussing Project synthesis, the 1982 AETS yearbook, and textbook-oriented teaching.

As teachers stand alone in their classrooms taking the fire from all sides, they gradually stop reaching out for help. Some have already closed their doors in frustration against the administrators and supervisors from whom they formerly expected and got support. We have asked teachers to do more with less until they are at the breaking point. There is a direct relationship between this situation and their ability to motivate students. Administrators, supervisors, and university professors can help by:

(1) Assisting in the "scrounging" of materials and delivering appropriate and usable items to the classroom.

(2) Designing in-service education sessions which address classroom problems directly. Most of the problems are not subject-area oriented.

(3) Working in the community to keep teachers' pay and working conditions comparable (at least) to those of firemen, policemen, and other community workers.

(4) Reorganizing the administrative structure (including report cards and student scheduling practices) to make the teacher's attention to student needs easier to accomplish.

(5) Being more willing to focus science education curriculum development on the needs of students and less on the structure of the disciplines.

(6) Supplying to teachers a believable rationale for the practices that are advocated.

Our own creativity in devising ways to support teachers as they work to support students is being challenged. Our own enthusiasm will infect the teachers that we can reach if we express the enthusiasm in deeds, not words.

## Why Aren't We Doing It?

It is tempting to answer this question facetiously by saying "because it's easier to just talk about it." There is so much food for thought in this chapter that one reacts to it emotionally rather than intellectually. If indeed we can learn to teach twice as well as we are now that will be satisfying. It will be "okay" that we are only teaching half as well as we know how, when that happy day arrives. Here we can read a superb summing up of the crunch in which science education finds itself. A partial answer to this chapter lies in the the next one.

## One Step At A Time, But Please Hurry

As teachers chart a course of improvement for themselves, supervisors can help by making careful observations of the teachers' strengths and weaknesses, followed up by thoughtful suggestions for making changes in the teaching behaviors. Teachers will repsond to in-service sessions which help them to learn new ways of interacting with students, new teaching models, and the techniques of inquiry teaching. The practices we advocate must be used to present the in-service sessions. Others learn as much from what the instructor "is" as they do from what he does. All of the suggestions given to teachers in this chapter can be adopted and adapted by the administrators and supervisors who often serve as models for teachers and students. All of us can gain satisfaction by taking one step at a time toward better serving the students for whom we have responsibility.

## Achieving Scientific Literacy Through Continuing Education

Once the decision is made that scientific literacy is the goal suitable for most of our student , this chapter offers continuing education as a way to help achieve the need to prepare teachers for assuming a major change in their responsibility to students.

The point is wisely stated that changes in teacher certification are necessary and that some sort of accountability must be built into the system so that teachers will be encouraged to change the goals they have for instruction. However, very few new faculty will be presenting themselves for training. The bulk of the teachers in service are already certified.

Supervisors and administrators have the task of designing in-service programs to suit local needs and to inspire teachers to consider themselves as professionals. The quantity of in-service training available must be increased and offered in more flexible formats, as this chapter suggests, but the validity and reliability of its content needs even more attention. This would seem to be a responsibility of cooperative planning between teachers and supervisors.

## Summary

In summary, statistics tell us that only a handful of science teachers are active in their professional organizations. It is not likely that many teachers will read the 1982 AETS Yearbook. Science teachers have been an elusive audience, in spite of a year-long effort to reach them. In practical terms teachers are members of the general public. An effort must be made to disseminate the findings of Project Synthesis and the AETS Yearbook through the public media, school board members associations, and school administrators. If the teachers' union leadership (AFL-CIO, not NEA) can be enticed into being socially conscious in dimensions other than those now occupying their attention, we may be able to get the attention of more teachers. The practice of talking to ourselves about the crisis in science education has not been very fruitful. Other avenues must be found.

Finding new avenues of communication will not be easy. Humans do not develop high interest levels about things that are scary or unknown to them. Our own superiors and colleagues unconsciously dismiss science from their minds as too complicated to think about. Have you noticed that sometimes your wishes or decisions are acceded to because no one has the courage to oppose you? On other occasions no one can hear what you say because of an avoidance reaction against delving into the unknown territory of science education. In turn, are you able to hear what social studies curriculum people are saying? Would you be willing to entertain the notions of writing a combined social studies/science curriculum? Many of us put a high value on the integrity of the discipline, while giving lip service to the interdisciplinary needs of our students.

New ways of thinking and operating must be found or devised by science educators if the carefully researched recommendations of Project Synthesis are to be adopted by teachers and curriculum writers. No crisis like Sputnik, which could save us (for the wrong reasons), seems to be on the horizon. One such possiblity, the energy crisis, is even now thought by some experts to be well on the way to solution.

We cannot, this time, stay in the background making bullets (new curricula, studies, reports) while teachers fight the war (by implementing changes). AETS has done the homework in fine style. We relish the thought of rolling up our sleeves (or maybe putting on our hard hats) to begin the task of moving into the next decades of science education. Never have we been better armed with more useful information than now. Each of us can plan and help to implement changes in our school community, by taking one step at a time.

# IT'S RATHER DIFFICULT TO DRAIN THE SWAMP..

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The Tylerian philosophy is alive in the 80's --- but not well. The problem is not with the philosophy, but rather with those who are attempting to use it during a period of rapid change. Before the type is set and the ink is dry on the purposes of education (Tyler's first goal), someone or committee of somebodies will decide on a new direction for science. Perhaps a new way to teach science, based on a new understanding of how children learn best or how teachers teach best, changes the goals. Maybe, the legislature of pressure from state departments of education and/or universities and colleges make the new direction obsolete. Then again, a local school district board of education might decide, in their wisdom, that "what you want to teach is not what we want at all."

Professor Yager's chapter entitled, "The Current Status of Science Education in U.S. Secondary Schools" reviewed 30 years of science education "highlights" and "lowlights." After millions of dollars invested in science education in the 60s and early 70s, his "Project Synthesis" committee indicates that "...an important step toward a solution is the recognition of a crisis---its magnitude, its complexities, its seriousness, its meaning." Most classroom teachers of science do not perceive a "crisis" situation but do realize that all is not well with what we are trying to teach, who we are teaching it to, and why we are teaching it.

Although most classroom teachers do not spend large amounts of time thinking about the nature of learning, they do attend meetings and read journals that seem to indicate a lack of direction for science. Many of them, products of the 60s and early 70s, find it difficult to understand what has happened to the ideas, ideals, and enthusiasm of the science education people of their college days. Why, they ask, isn't there a new direction, with new leadership in science education? What happened to the early 70s goal of developing scientifically literate citizens?

Scientific literacy is the goal of science education, as pointed out by Peter Rubba. Unfortunately there does not seem to be unanimity on the part of the science education community as to what constitutes a scientifically literate citizenry. This lack of agreement causes the classroom teacher to be even more paranoid. How can a teacher plan and/or select instructional objectives for a goal which no one seems able to define? Further, without definition, it is quite impossible for teachers to develop an evaluation procedure for textbook adoptions, laboratory experiences, or student evaluations.

There is no doubt in my mind that Tyler's goals are as useful today as when they were promulgated more than 30 years ago. However, as every author in this book points out, there are tremendous problems within the discipline known as science education and the art of science teaching. Berger's "Vignettes" of teaching science are closer to the truth than he realizes. Additionally, references to pressure groups, students with special needs, teaching and learning styles, and problem solving processes indicate the many outside areas of concern to the classroom teacher.

I am in total agreement with Dr. Herron who states that, "Most of us only teach half as good as we know how." With the many pressures on a classroom teacher such as student and teacher competency tests, certification changes, declining SAT scores, grade inflation, low self-esteem from the community, negativism on the part of journalists and commentators, and a myriad of daily concerns brought about by parents, students, and administrators, it is unfortunately not an overstatement by Dr. Herron that at present, "The teacher's task is humanly impossible."

I concur with Professors Prisk and Staver that Professor Andersen's "Holistic" model for the 80s is a good one. I do cringe, however, at the thought of asking veteran staffers to teach philosophical, historical, and futuristic science curricula without the benefit of training in these areas. Remember, these teachers are the products of the knowledge intensive science curricula of the 60s. Few self-respecting science education departments in those days permitted much exposure to the liberal arts.

Certainly, in-service education could and should be used to retrain, but in many rural areas this updating is not readily available. The suggestion that staffers in a 50-75 mile radius get together and compare ideas is not realistic for vast areas of our country. In fact, communication between schools within the same community is sometimes so poor that science staffers in one school barely know their opposite numbers. The question is not "should these professionals meet and articulate their goals and problems", but rather "how do we make these meetings possible?"

In-service education has been touted by many as the salvation of education and should be required for continued employment. I agree, but with several reservations: 1) Who is going to pay for the instruction? 2) Which is the staffer going to attend? 3) If on his own time, who will compensate him for his time? 4) Will the in-service program do for a burned-out, unmotivated individual what its objectives state? Apathy is very deep in the ranks of veteran instructors because the promises and ideals that led them to the classroom are proving false.

I do not believe that the problems of science education are so overwhelming as to be impossible to correct. The authors of this volume will do much to communicate the problems of science education to many others at the collegiate level. Let us hope science education specialists read and take to heart Tyler's approach to science education, along with the research findings and suggestions found on these pages. The specialists should realize that, more than anyone, they can influence elementary and secondary science education toward its goal of scientific literacy in the 80s.

The science educators at the college level must assume a leadership role in training classroom teachers to develop scientific literacy goals in the curriculum. They must also influence textbook authors to include the new findings of research in their books since most school curricula <u>are</u> the textbooks. In addition, AETS could take a leadership role in evaluating the new science programs and texts, critiquing them by comparing them to a set of goals developed on Tyler's model. To ask a classroom teacher to do all of the many self-improvement tasks suggested in this book is not realistic. Teachers need your leadership help to show the way out of the present science education wilderness. When asked, "Why aren't you developing your own curriculum to meet Tyler's goals?" most honest classroom teachers will tell you, "It's very difficult to keep your mind on draining the swamp, when you're up to your ass in alligators."

# CAN THE SCIENCE EDUCATION COMMUNITY MEET THE CHALLENGES OF THE 80'S?

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The central purpose of this chapter is to provide a reaction to Parts I and II of the Yearbook. The reactions are organized into the following sections: (1) Progress During a Crisis; (2) Selecting/Developing and Using Conceptually Sound Curriculum Models; (3) Developing Curricula at the Local Level; (4) Improving Science Teacher Education; (5) Removing Barriers to Effective Science Teacher; and (6) Concluding Remarks. In an attempt to be parsimonious and have clarity, as suggested in the chapter by Prisk and Staver, "Science Educator" is used throughout the chapter to refer to college- or university-level persons associated with the education portion of science teacher education programs, curriculum development, and associated research. "Science education community" refers to science educators, scientist and university science teachers involved in teacher education and curriculum development, science supervisors, and science teachers at the secondary school level.

## PROGRESS DURING A CRISIS

Although conditions currently exist in science education that are unsettling, the re-discovery or possibly discovery, depending on the individuals involved, of Ralph Tyler's rationale or principles of curriculum and instruction (Tyler, 1949) by members of the science education community is a welcomed state of affairs. It is an advancement that is long overdue. Even though Tyler's work has been available for more than 30 years, it has not been used previously to any appreciable extent by the science education community in the development or analysis of curricula at any level. However, it is not unusual for progress to be made during times of crisis. The re-discovery of the Tyler rationale is evidence that the science education community may be on the verge of making significant progress in response to the current crisis. Further evidence is that all but one of the chapters in Parts I and II of the Yearbook reflect optimism, pointing out the merits of the Tyler rationale for analyzing curricula, establishing goals, selecting textbooks, and developing science teacher education and science curricula.

Progress can be made with respect to other problems facing science education if the science education community takes the challenge offered in the chapter by Yager and acts accordingly. For example, Herron refers to an article by Weaver (1979) and states that students entering other professions have higher intellectual capabilities than teachers. His position is supported by Schlechty and Vance (1981). If this is true for science teachers, and the science education community wishes to alter the situation, now is a good time to begin, because the current crisis offers the opportunity. Science and science-related majors at the unversity level are finding increasing difficulty in securing employment in their chosen fields upon graduation. At the same time, there is a shortage of science teachers at the secondary school level, and it appears that this shortage will be even greater in the immediate years ahead. This provides the opportunity for active recruitment and training of prospective science teachers who have higher intellectual capacities, provided that greater cooperation and communication can be established between the university science community and science educators. One might argue that recruitment took place in the past, and we ended up with the teachers we have today. After all, how many science teachers at the secondary school level started their post secondary school education with science teaching as their goal? The facts are that most drifted or were counselled into science teaching without being recruited, with the reasons being as diverse as the population. The key to progress toward raising the mean intellectual capabilities of science teachers would be the establishment of better cooperation and lines of communication between the university science community and science educators and a program of active recruitment. Such a beginning is not without its pitfalls, but the opportunity exists.

Even for the purposes of debate it would be naive to suggest that active recruitment by itself would result in a significant increase in the mean intellectual or academic capabilities of science teachers. Part of the problem is that many intellectually talented teachers leave the profession. Schlechty and Vance (1981) found this to be the case in their study of North Carolina teachers. Active recruitment could be a beginning, but real progress will require the elimination or amelioration of a substantial number of the barriers identified in the chapter by Herron that limit teacher activities and effectiveness, barriers which no doubt adversely affect teacher retention. It will further require improved programs of science teacher education, higher admission standards, and an investigation and possible revision of existing certification and hiring practices.

Another example where the crisis facing the science education community has the potential of resulting in progress is related to the science component of preservice and in-service teacher education. Prisk and Staver are absolutely correct when they point out in their chapter that university science courses dwell almost exclusively on the empirical aspects of Andersen's model at the expense of the futuristic, historical, aesthetic, and philosophical areas. During the 1960s the science education community knew what science teachers needed--more basic science selected by the unviersity science community. Today, many science educators realize that this over-emphasis on basic science for teachers was a mistake. The position of scientists and university teachers remains about the same, but conditions have changed. As enrollments at the graduate and undergraduate levels in science education began to decline in the early 70s, enrollments in university science courses declined, but the university science community still had its basic research funds and majors. During the latter part of the 70s, basic research funds and majors in science declined. As a result, student credit hours have taken on a new meaning for the university science community, particularly during summers. At least on some campuses the crisis has caused selected members of the university science community to be more receptive to suggestions concerning course offerings and content covered in the courses. They appear to be more amenable toward entering into cooperative rather than dominative relationships with science educators. It is a good time for science educators to cultivate cooperative relationships and possibly bring about changes such as including futuristic, historical, aesthetic, and philosophical areas into the science component of their pre-service and in-service teacher education programs.

The preceding examples are not a mandate of what should be done. They are rather examples of what could be accomplished by taking advantage of the current crisis. Many other possibilities exist. It is up to us, members of the science education community, to get together and establish comprehensive courses of action based on established goals, and to implement these plans as suggested by Andersen, one step at a time.

## SELECTING/DEVELOPING AND USING CONCEPTUALLY SOUND CURRICULUM MODELS

The effective development, revision, and analysis of curricula require a conceptually sound curriculum model. Therefore, if members of the science education community wish to make advances in these areas, they must choose, modify an existing model or come up with conceptually sound models of their own. But the question arises: What are the characteristics of a conceptually sound curriculum model? This question has been largely ignored by the science education community in the past, but it needs immediate attention. In order to initiate a dialogue on the question, the following is a rudimentary list of the characteristics of a conceptually sound curriculum model, drawn in large part from an analysis of and reaction to the Yearbook and Tyler's rationale. Such a model should

1. contain a process for determining objectives which takes into consideration the nature of the learner, society, and knowledge;
2. provide for balance with respect to emphasis placed on the nature of the learner, society, and knowledge;
3. consider learning psychology and philosophy of education in the process for selecting objectives;
4. utilize objectives to select and organize content, teaching procedures, learning activities, and materials;
5. provide for reality checks;
6. make provisions for gathering and utilizing feedback during development and implemenation;
7. utilize objectives to plan and implement a comprehensive program of evaulation;
8. provide guidelines or principles for the decision-making process.

Other characteristics include that the model has wide applicability and be unpretentious, flexible, and usable.

A majority of the authors in Parts I and II of the Yearbook give the impression that they are aware of the need for curriculum models that are more conceptually sound than the ones the science education community has used in the past. Their enthusiasm for Tyler's rationale is understandable because it does meet several of the previously listed characterisitcs of a conceptually sound curriculum model. Tyler's rationale certainly is an improvement over what should be called the Zacharias course content improvement model, which has dominated science education curriculum efforts for the past 25 years. The Tyler rationale is, however, not without its shortcomings as a curriculum model. This should not be surprising since Tyler did not intend, at least initially, for his rationale to be viewed as a curriculum model. He states:

> This syllabus attempts to explain a rationale for viewing, analyzing and interpreting the curriculum and instructional program of an education institution . . . It is not a manual for curriculum construction since it does not describe and outline in detail the steps to be taken . . . to build a curriculum. (Tyler, 1949, p. 1)

Tyler points out one serious shortcoming of the rationale. Additional shortcomings as well as strengths of the rationale are discussed at length in the chapter by Rubin in an insightful and positive manner. The science education community would be well advised to follow Rubin's lead and further examine the rationale in even greater detail.

Initial enthusiasm over the merits of the Tyler rationale must not cause members of the science education community to become complacent and discontinue their search for an improved rationale for use in curriculum analysis, revision, and development. An important point to realize is that Tyler never viewed his rationale as the final product for others. He states: "The student is encouraged to examine other rationales and to develop his own conception of the elements and relationships involved in an effective curriculum" (Tyler, 1949, p. 1). Members of the science education community need to react to Tyler's encouragement and attempt to develop their own conceptually sound curriculum models. In accomplishing this task, consideration should be given to the following items: (1) rationale by Tyler; (2) analysis of the rationale presented in the chapter by Rubin; (3) analysis of the rationale by other curriculum theorists within and outside science education; (4) other existing models and rationales, such as Andersen's holistic model (Andersen, 1978), described, in part, in the chapter by Andersen and again in the chapter by Prisk and Staver; and (5) analysis of past curriculum efforts as described in the chapter by Yager. It would be unwise not to examine, debate, and utilize what has already been accomplished. In addition, members of the science education community must come to grips with what consitutes an effective curriculum model; i.e., the characteristics of a conceptually sound curriculum model.

## DEVELOPING CURRICULA AT THE LOCAL LEVEL

Numerous statements throughout the Yearbook support the position that attempts to develop and implement curricula at the national level have had pitifully little impact on the classroom behavior of science teachers. This failure to bring about the specified changes is further echoed throughout any number of professional articles, research documents, and books. Many reasons are given for this phenomenon, but one that surely played a prominent role was that teachers who were to implement the curricula were not involved in the development and did not accept the curricula objectives as their own. Yet, as incredible as it may seem, a general attitude is still held by a large number of the members of the science education community that local curriculum efforts cannot possibly be as good or effective as national projects supported by government, scientific and professional associations, foundations, and/or universities. In fact, if one listens closely, mutterings can still be heard that national curricula will work if curriculum developers use better models, select more appropriate content, revise objectives, improve teacher training, have more resources, include student interests, ad infinitum. Members of the science education community are advised to carefully read the excellent chapters in the Yearbook by Beisenherz and Berger. They should shout Berger's title, "But...It Doesn't [or Didn't] Work For Me," every time they hear one of these mutterings. They should shout even louder, substituting "Won't" in the title, when they have an urge themselves to continue the practice of developing national curricula for implementation by teachers who had no part in the development.

Frymier and Hawn (1970), Harmer (1977), Frazier, (1964), and Goodlad (1976) provide the science education community an alternative approach which is supported at least in part by several of the Yearbook authors. They feel that effective curricula not only can, but should, be developed at the local level. The approach provides greater potential for bringing about changes in the classroom behavior of science teachers, because the teachers become active participants in the process. It is time to realize that taking part in the process of curriculum development is an experience that is crucial for changing the implementor's classroom behavior, an experience that cannot generally be obtained vicariously. Further, national curricula cannot be developed that are suitable for all science teachers and students of a particular subject and grade level. Teachers and students are different, and so are local needs, concerns, and interests.

Local curriculum development does not mean that scientists, university science teachers, and science educators will not play important roles. In fact the approach will require their involvement in even greater numbers. Their expertise will still be desperately needed; however, their roles must change. They will no longer dictate curriculum but will assist, encourage, and support others in the development and implementation of curricula.

## IMPROVING SCIENCE TEACHER EDUCATION

Each author in Parts I and II of the Yearbook has considered Tyler's rationale and suggested proposed courses of action in response to selected aspects of the crisis facing science education. A variety of excellent proposals are made, most of which will require a number of changes in science teacher behavior. The following are among the proposed behaviors that science teachers are to acquire:

1. Use curriculum models in developing, revising, and analyzing curricula

2. Implement a variety of teaching activities and tactics

3. Foster intrinsic motivation in students

4. Pursue a broader range of goals

5. Make teaching fun for themselves

6. Organize instruction around student interests

7. Include reality checks in establishing instructional goals

8. Use goals to analyze and select textbooks

9. Foster positive student self concepts

10. Expand presentations of science content basic knowledge

If behavior changes such as these are implemented, significant improvements will have to be made in pre-service and in-service programs of science teacher education. For the most part the Yearbook authors do not deal specifically with the question of how to improve science teacher education, but it is clear that this question must be considered and overtly acted upon if their proposed courses of action are ever to become reality.

Space does not allow a long discourse on how teacher education should be improved in order to bring about changes in science teacher behavior. Nevertheless, it would be unconscionable not to raise one further question: How can science educators and university science teachers expect secondary school science teachers to exhibit behaviors such as those proposed by the Yearbook authors, unless they themselves exhibit the behaviors as they teach pre-service and in-service science teachers?

## REMOVING BARRIERS TO EFFECTIVE SCIENCE TEACHING

Although Herron overstated several points, his chapter was thought-provoking and contained enough truth to cause even the most optimistic member of the science education community to have, at least, a momentary period of depression. One statement, however, particularly needs to be challenged. Effective teaching is difficult but not humanly impossible, as Herron contends. They may not be members of the majority, but many science teacher are doing an outstanding job in spite of the barriers working against them.

Herron's chapter brought to mind another old farmer story, one in which the farmer uses a two-by-four to get his mule's attention before giving him directions. Space does not permit the entire story, but the analogy is obvious. Herron may not have intended it as such, but the previously identified statements and others, such as "most of us only teach half as good as we know how" and "rather than insulate individuals from those truths that prick the tender skin, we can work at developing more calluses," should serve as a two-by-four and get the attention of members of the science education community who read the chapter. In keeping with the analogy, a course of action (or directions) is suggested by Herron in which realistic solutions are proposed for specific barriers to effective science teaching.

The following scenario is not dealt with in its entirety by Herron but illustrates his approach. A barrier facing the science teacher is the lack of political and public support of science and science teaching. This is true even though a Nobel prize winner in medicine recently told science teachers at a convention that a good part of her interest in science could be attributed to one of her science teachers. Another Nobel prize winner in chemistry recently paid tribute to the organizer of a high school science club by indicating that she was instrumental in his becoming a scientist. Several documents are available making the case that improved science and science teaching are in the best interests of national defense. A great deal more information of this type is available, but almost none reaches the general public. If it reaches politicians, they do not react because of the lack of public support. A realistic approach to this problem is not reorganizing curricula, but for the science education community to follow the example of other groups in society who have been successful in securing public support. They need to immediately organize, plan, and implement a massive public relations campaign, capitalizing on public broadcasting media.

The chapter by Herron causes a question to be raised. Why have members of the science education community, past and present, limited themselves primarily to activities such as restating goals of science teaching and reorganizing the curriculum, and generally not engaged in planning and implementing realistic solutions to specific barriers to effective science teaching? This is not to imply that restating objectives and reorganizing the curriculum are unimportant. All these activities must ultimately be accomplished. It is a matter of priorities and a reality check to determine what will have the greatest immediate effect on science teacher effectiveness. Herron's proposed course of action utilizing reality checks is a good one. The science education community would do well to use the approach in their attempt to identify a sense of direction for the 1980s and beyond.

## CONCLUDING REMARKS

The current crisis is forcing the science education community to sit back and analyze where it has been, where it is now, and where it plans to be in the future. Without the crisis it is likely that the science education community would be doing business as usual; i.e., attempting to implement some modified versions of the national science course content improvement projects without really examining the objectives of science teaching. One of the major concerns would likely be how to implement the revised course content improvement project more effectively. But the crisis is real as the 1980s begin, and, as Yager points out, it provides the science education community with challenges which can be turned into Opportunity. The question is, can the science education community meet the challenges of the 1980s?

Whether or not the science education community can turn the crisis into opportunity and meet the challenges of the 1980s cannot be answered a priori. Only time and analyses of what takes place will tell. The re-discovery of Tyler's rationale, its use, and the optimism tempered with Herron's realism in the Yearbook are good signs or precursors of success. The challenges may be met if the science education community (1) identifies a sense of direction, (2) removes some of the barriers to effective science teaching, (3) secures better cooperation and establishes better lines of communication among its members, (4) improves in-service and pre-service science teacher education, (5) encourages and realizes wide-scale local curricula development and implementation, (6) utilizes conceptually sound curricula models, (7) employs reality checks, and (8) implements many of the excellent proposals suggested by the Yearbook authors. This is a large number of "ifs," and they reflect one person's bias. Nevertheless, how well they are met will determine, in part, the science education community's success at meeting the challenges.

A further, and possibly more crucial, test will be the answer to the following questions. When the crisis subsides or changes, as it surely will, and the science education community once again enjoys public support and resources, will the efforts to meet the challenges of the crisis be set aside? Will the science education community begin again and make the same mistakes it made in the past?

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## FROM ONE HIGH SCHOOL CHEMISTRY TEACHER...

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### OVERVIEW

It was interesting to note the degree of overlap and commonality in the chapters of Parts I and II. Tyler's rationale for curriculum was well explained by Rubin, and, consequently, aspects and/or modifications of his model were used throughout the following papers. Other continuous threads were found in various authors' treatment of the critical role of the teacher (Rubin, Berger, Andersen, Beirsenherz, Yager, Rubba, Herron, and Prisk and Staver); the central role of the textbook in curriculum development (Yager, Herron, Rubba), the need for in-service, pre-service, and continuing education for science teachers (Rubin, Yager, Herron, Prisk and Staver); the individualization of the science curriculum (Yager, Andersen, Prisk and Staver), the inherent difficulty in making changes (Herron, Andersen) and the motivational factors necessary for both teachers and students in an effective teaching-learning process (Berger, Bisenherz, Herron).

While each of the authors had a specific frame of reference which will be addressed later, the areas of agreement were remarkably parallel. Elementary and secondary teachers would easily recognize the specific areas in need of change, and would also quickly agree about the difficulty of coping with these components of the overall problems of science education. However, the statements describing these areas are often verbose and unnecessarily complicated. Classroom teachers can, in many cases, come up with a similar "laundry list" couched in simpler language. This may possibly be a carry-over of the classroom technique which requires teachers to explain concepts and ideas and/or give directions in a clear and concise manner. The more directly an objective is stated, the more likely it is to be achieved, since its implications are more easily understood. If, as Herron states, "less competent, more passive, more poorly prepared people enter the teaching professions," how are these people able to cope with complex goal statements and curriculum developments described and prescribed by "higher level" science educators? As Herron contends, they don't...they fail to meet these expectations. I would suggest that there is a disjunction here, one between the tertiary level educators and the elementary and secondary level educators. Prisk and Staver might have stated this as a mismatch of teachers and teachers! While Herron's statement may reflect an opinion held by many lay people and science educators, a significant number of classroom teachers are working at their level by choice, and, in fact, avail themselves whenever and wherever possible of outside educational experiences. This is supported by Andersen's observation that there is less "burnout" among science teachers than in the rest of the education profession.

The most significant outcome of the previous chapters is the agreement that scientific literacy for the citizenry should be the paramount goal of all science education today. This does, indeed, entail a great amount of rethinking and retooling of our entire science education community, from kindergarten through the tertiary level. Historically, there has been wave after wave of curriculum development as the needs and interests of the public wax and wane. How many of these new or revised curricula actually affect the students? This crisis is not new...it has been with us for a very long time. Unless the curriculum developers have a real impact on the classroom teacher, by whatever means necessary, the new and as yet undeveloped curriculum to develop scientific literacy for the citizenry will remain a subject of study, discussion and a basis for arguments by professors of education, but not a reality for students.

## THE TEACHER

The critical role of the teacher is mentioned over and over again. There is agreement within the profession that the teacher is the single most important factor in maintaining student interest, in imparting knowledge, in sparking enthusiasm for subject matter and for learning in general, and when acting as an adult role model for students. Rubin, Andersen, and Berger speak eloquently about the artistry of teachers. This is the quality which I have always maintained is the very essence of a good teacher. The flexibility (Berger, Beisenherz), the capability to capture the "ripeness" of the moment (Rubin), the decision-making responsibility (Yager, Beisenherz, Andersen, Rubba), and the necessity of being invloved in curriculum design (Yager, Beisenherz, Andersen, Rubba) are all worthy objectives of institutions and organizations responsible for teacher preparation.

Pre-service, in-service, and continuing education opportunities to upgrade the scientific literacy of teachers as described by Prisk and Staver is a terrific idea. But, how? Prisk and Staver have suggested one possible mechanism. I'm sure others can be developed. The crucial point is administrative support. If the requirement were imposed from the outside [i.e., for teacher certification (Prisk and Staver)], school boards would have no choice but to support those efforts. The intrinsic motivation of teachers is not enough to make this possible on a scale large enough to realize the previously mentioned objective.

A teacher who is challenged, who is having fun (Berger, Beisenherz), can be the greatest motivator for students. Beisenherz's discussion of motivation, direction, and intensity as an indicator of students' behavior was very much to the point as seen in the classroom. The definition of intrinsic and extrinsic motivation could, and should, be equally applied to the teacher. Some of Herron's realism (or cynicism) could be addressed if science educators, school boards, and communities gave credence to this reality. If both the extrinsic and intrinsic motives of the teachers were recognized and validated, they might do a better job with their students!

Herron's proposals with regard to having a teacher become a voting member of a school board would be untenable in a community where teachers and school boards engage in the collective bargaining process of contract negotiations. It would appear to be a conflict of interest. The idea of a principal serving "only at the pleasure of the faculty" precludes the usual type of administration line and staff responsibility table. A sensitive, competent, effective principal is indeed the keystone of a good school, but giving the faculty the full power over his/her job seems unrealistic. However, the faculty certainly should have an equal opportunity, with central administration, to voice its feelings in its evaluation of the principal.

## THE CURRICULUM

The goals for a curriculum designed to develop scientific literacy must meet personal needs of students, must deal with societal issues, must prepare future scientists, must deal with career awareness (Yager), but must not be vague and impossible to achieve in the classroom (Herron). The discrepancy between the desired and actual states of science education must be crystal clear in order to determine a starting point for curriculum development (Yager). The question of values in determining the goals of a curriculum is a sticky, but critical issue and needs much community involvement.

Problem-solving as one of the main goals of a curriculum (Rubing, Berger, Herron) can be used as a vehicle for so many of the other goal requirements set forth in the previous chapters. The open-ended inquiry type laboratory exercises of previous curricula (CBA and CHEMS, for example), were gradually abandoned by many chemistry teachers because they were difficult to evaluate, difficult to set up, difficult for students to think through with their limited experience. Such activities were, in short, more effort than they were worth in the opinion of many teachers. But they were, in fact, typical of the type of activity needed to teach students the skills needed to solve problems. The fallacy of these earlier curricula was in developing these skills in only one setting... the laboratory (Berger). If these skills were developed by also using case studies, by looking at historical perspectives and their impact on the future, and/or by other developmental processes, similar to the holistic approach of Andersen, then the scientific literacy with respect to looking at and solving societal, cultural, and technological problems would be greatly enhanced.

The use of the textbook in determining a curriculum is a typical "cart before the horse" situation (Yager, Herron, Rubba). But whose fault is this? Again, if teachers have neither time nor expertise to devise a curriculum but can choose the text, why shouldn't they choose that which is easiest to use, most understandable to them, most interesting to them (not necessarily to the students), that comes with the greatest amount of supportive materials, the book, in short, that will make their job easier? That is not to say that these texts are necessarily unsuitable, but they may not have the same set of objectives as the curriculum designers who opt for scientific literacy for citizens.

Finally, in dealing with curriculum design, the need for individualizing the science curriculum appears to be the only logical way to meet the various needs of students and society (Yager, Andersen). While there is agreement that this is the ideal methodolgy to teach anything appealing to the interest of individuals, sparking the imagination of each student at his/her specific level of development, it is difficult to see how this can be adequately done in the present day context of shrinking budgets, larger classes, and lower teacher morale. Herron realistically speaks of "built-in" failure. The attempt to individualize without sufficient support system is a sure path to failure. Therefore many teachers and school systems will take the easier, apparently more successful and certainly less expensive route of group teaching-learning.

## SUMMARY

If the goal of scientific literacy for all citizens is primary, all efforts must be made to effect change by involving classroom teachers in the massive job of curriculum revision with clear-cut, realistic, achievable goals. The education of school boards and government agencies toward this end is critical. Support must be broad-based, and cooperation must be gained between all interested groups so that students will benefit from this change.

# WHAT SCIENCE TO TEACH AND HOW TO TEACH IT? NOW THAT'S A PROBLEM!

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Which science courses should students take? What should the content of those courses be? All of the authors refer to these problems and raise some valid questions.

Have school systems forgotten the reason for their existence? Especially with the financial quandary in which schools are finding themselves, shouldn't they go back to providing a liberal education? Andersen indicates that we are preparing future scientists, not the general public. Is it really the job of the public schools to provide specialty courses or courses so advanced as to allow students to "test out" of several college courses?

As the authors, almost to a person have indicated, science education needs to provide the average citizen with a background with which he/she can exist in our technological society. Rubin questions whether we should have, as our goal, citizens to "fit in" or to "change" society. We in science are directly influenced by the attitude of the populace and its governing body. If citizens don't understand science, it is our fault, for we had (or should have had) the opportunity in the classroom to enlighten and prepare them.

How to teach science? Now that is a problem! What is a good way for the teacher to teach may not be a good way for the student to learn. The fact of the matter is that educators today are forced to teach all students. According to Resnick as reported by Schneider (1981), p. 2 a major reason we have so much difficulty meeting this country's literary standard is because we've moved very fast in our efforts to teach difficult learning skills to large populations. "Remember that only the last three generations in this country expected all children to reach acceptable literary levels, with the big push coming after World War I."

The early schools had only to deal with a small number of projects. And these students, by and large, were highly motivated and well supported at home in their academic endeavors. If they couldn't make the grade, they dropped out; most made it. The fact of the matter is that today educators are forced to teach all kids. And yet, instructional methods suitable to large and diverse populations, rather than small and select ones, have not yet been successfully developed or applied (Schneider, 1981).

I agree with Herron that memorizing facts is not always the best way. It is the reasoning behind the facts that is important and long lasting. Stein (1976) stresses learning beyond memorization of facts and acquisition of skills. He feels that the essence of scholarship is the ability of the learner to exhibit these capabilities: reading with understanding, evaluating evidence, expressing one's ideas, finding information, understanding where "facts" come from, and the habit of learning. However, all science education must change, or else the student will not be prepared for the achievement tests or the next level of science which assumes a background of memorized facts.

Continuing with the subject of methodology, Herron expresses the need to bring all environments together in dealing with many of the issues in the classroom. NOVA, National Geographic, etc. have done much to bring science to the general public but one must be attuned to the specialized atmosphere of one's own classroom and effectively teach for that particular environment. There are <u>many</u> good ways to teach despite the enthusiastic reports of publishers and curriculum developers. No single curriculum works for all teachers, according to Berger.

Textbooks cannot cover all of the needs of such a dynamic subject as science. The science teacher needs to make use of periodicals, newspapers, and, yes, even the sometimes offensive television. Don't be afraid to change lesson plans. Berger advises to not worry if something new doesn't succeed. What better way to depict the attitude of research than to adapt and change with the mood of the day. Beisenherz points out how important the efforts of the teacher are in comparison with the textbook; otherwise, teachers could easily be replaced by the computer.

In a 1976 NABT survey, the highest priority was given to improving students' motivation (Creager, 1976). Science teachers must be acutely aware of the diversity that exists among their students. Although some students are planning to be scientists, for others this first science course may be their last. Students' interests and abilities will vary tremendously, but the science teacher must address them all, and capture and hold their interest. Teachers cannot simply cater to the potential scientist in the classroom. They must fill many roles in addition to presenting their subject in an interesting and effective manner (Mariner, 1978). Beisenherz writes about student attitude and its effect on motivation. Teachers must consider the attitude of the student toward not only the subject matter, but also toward himself or herself.

Individualized instruction, mentioned by both Andersen and Yager, is not a panacea for all problems, but it seems to provide for the interest of all students in many areas. The individualized course can be adjusted to fit the needs of the student rather than an unacceptable compromise.

Continuing education represents an important direction for action and a necessity that stems from the fact that knowledge changes. Maurer writes:

> Our knowledge of ourselves, our planet, and our universe continues to unfold at a grea rate. The way we use that knowledge will challenge the existence of not nly every organism on this planet, but also the existence of the anet itself. Whether or not we can deal with this challenge remains o be seen, but one factor will contribute significantly to our success or failure--formal education (Maurer, 1979, p. 434).

How does the science teacher not only keep pace with developments on the frontiers of science, but also decide what is significant and necessary for students going out into the world to make important decisions (Maurer, 1979)?

Yager, Herron, Prisk and Staver all refer to the problem of science teachers trying to keep pace with the latest developments in their areas. Ways to keep abreast of recent events could be to attend the many conventions, seminars, and mini-courses now available. These are compact, informative sessions which are not as time-consuming as regular college courses. Another way for teachers to not only gain new information, but also to actually regain diminished enthusiasm is to become involved in science student competitions in one capacity or another.

Unlike business and industry, education does not provide for a change in job responsibilities or even in environments (same classroom for 30 years). Prisk and Staver explain the positive results that have come from teacher interchange among school districts. This effort would do a lot for elimination or prevention of stagnation in the classroom. Exchange of ideas and new challenges are always important. Unfortunately, not all teachers take, or are even given, the opportunity to find out how they compare with their fellow teachers.

Throughout several of the articles in the 1982 yearbook, the Sputnik age is discussed. It is a bit ironic how much of a catalyst that Russian project turned out to be. Here we are in the 1980's, finding that the attitude of the public toward science is somewhat apathetic and, at times, even hostile. The public wants science to solve problems but to create none, according to Rubba.

Reading press releases concerning education has to affect students considering a career in science education and, indeed, science teachers themselves. School administrators have lamented the fact that industry and business are luring away not only potential, but also existing, teachers. Better salaries and fewer hassles seem to be the resons for choosing a noneducational profession. Andersen has indicated that career orientation is affected by our economy. And yet, who are the people giving the students the opportunity to become doctors, chemists, etc? Of course, they are teachers!

I agree with Herron that "most of us only teach half as good as we know how." All of the concerns about the status of science education are valid and the solutions sound, but I suggest that there is another serious problem developing that needs attention. The lack of science teachers in the classroom or the presence of frustrated teachers is a very real concern. First, we want to encourage students to become science teachers and then to keep them in the classroom. A change in public attitude is needed. Teachers need public support, not the teardown and blame-all attitude that is being conveyed. Only then can we be concerned with science education itself. Then we will have teachers in classrooms anxious to continually do the right thing by students, not teachers feeling that no matter what they do, something else is desired.

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# WHAT WE CAN DO!

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There is little doubt that Ralph Tyler's thinking (1949) has made major contributions to both general curriculum and instruction and to science education over the years. Most of the Yearbook chapter writers, as well as myself, first experienced his work as undergraduate students, or as beginning science teachers. Later we became reacquainted with it as doctoral students, and still later incorporated much of his thinking in our own methods classes and graduate courses. Professor Rubin gives an excellent account of Tyler's work in this volume. But it is important not to ask more of this rationale than it was designed to deliver. As Rubin points out, "Its timelessness, of course, stems from the fact that it provides -- not solutions -- but procedures for finding solutions." As science educators I think we can be confident, as evidenced from this volume, that we have gone as far, in describing the various ramifications of the problems facing us, as the Tyler rationale can lead us! Yager's and Rubba's efforts at pulling together and summarizing a number of nationwide surveys and studies probably provide us with more information about student interests and characteristics, social problems and trends, contributions from the science disciplines, goals, objectives, and methods than we either have the skill, time, or energy to pursue.

Although most of the authors in this volume moved from some form of the above information to suggestions for new directions and overall improvement, Professor Herron's paper was most illuminating and compelling as he candidly described existing conditions requiring that teachers and schools fail, and cautioned us to attend first to what we "can do" and consider what we "should do" next. In his words:

> It should be clear that changing educational practice can be extremely difficult, and even though Ralph Tyler's rationale for curriculum development may be sound, it is incomplete. In addition to considering what goals are proper, we must consider what goals are possible; in devising the strategies to accomplish goals, we must not lose sight of real barriers that limit our activities; in evaluating outcomes we must guard against doing simplistic evaluation that masks our failures, or setting unreasonable standards that hide the accomplishments that are made. In such a spirit of realism, it would be foolish to suggest action that would be appropriate for every teacher of every school system, yet it would be irresponsible to outline problems without suggesting the direction to be taken for solutions.

Most conditions we face during curriculum development, dissemination and evaluation, teacher training, and instruction in the schools include constraints. We need to determine in each context what these constraints are, whether we can function within them; and what <u>can</u> we <u>do</u>, and then set about doing it.

A number of the authors in this volume addressed pre-service and in-service teacher education in the sciences, but few focused on the influence the authors themselves can have in their own institutions in this regard. We can as professional science educators, influence science teacher education programs in Colleges of Education. We can recruit the best and the brightest to enter science fields and science teaching. We can, as teacher educators, provide teachers with skills that transcend particular textbooks and curriculum packages, so they can adapt to changing needs and demands in society and incorporate them into their courses. We can influence undergraduate science programs in our universities so that each undergraduate student experiences studies in the history, philosophy, and sociology of science as well as science courses. We can shape these experiences so that this knowledge can be translated into usable methodology if and when they became teachers. We can, as science educators, both create and disseminate up-to-date information on research on teaching, learning, and curriculum to teachers of science, as Beizenherz, Berger, and Andersen illustrate in their chapters. Finally, as Rubin points out, we can help teachers and others to set realistic and attainable curriculum and instruction goals and operationalize them so that attainment is public knowledge. These are just a few things we can do to add to the myriad of suggestions found in the chapters of this volume.

Two themes seemed to implicitly and explicitly recur in each of the papers in one way or another. One is the need for different, or at least expanded, goals for the 80s and beyond, and the other is the implication that science teachers bear the major responsibility, accountability, if you wish, for student performance. Some reflections on these two areas would be in order.

We in science education have been discussing the changing goals and objectives of instruction for years. It is realistic to assume that as society changes some issues and content become of relatively more utility than others. For instance, Yager, in his discussion of needs for future years, points out:

> The science education leadership (surveyed) was in general agreement as to the direction for such changes in goals. Most saw a focus on the science and society interface, the use of science in daily situations, value and ethical dimensions for science, and an emphasis on problems and the future as new kinds of emphasis for school science.

Do these "new directions" require changes in curriculum materials, teacher behavior, classroom texts, administration? Perhaps some changes. But, we should not lose sight of the fact that we are speaking in many cases of application and generalizability of knowledge acquired in each of the "new" goal areas Yager's summary identifies. Modifications in instruction should include learnable capabilities that permit learners to do the above for themselves. For instance, Wittrock (1979) and Gagne (1980) point out that learning from instruction is studied more productively as an internal cognitively mediated process than as a direct product of the environment, people, or factors external to the learner. This view emphasizes the active and constructive role of the learner. Learners are active, responsible, and accountable for their role in learning. Perhaps we as science educators have spent too much time attempting to influence texts, curricula, and teachers and have not given enough attention to detecting ways to help learners become better learners. After all, if we as science educators recognize these emerging "new goals," certainly prepared learners and their parents, and teachers who read newpapers and watch the TV news are also aware of these changes, problems, and issues! What learners need to do is relate what they are learning to these new problems and issues. Wittrock (1979) goes on to point out in this regard that it is more useful to consider how teaching style influences the learner's attention, motivation, and understanding, which in turn influences behavior, than it is useful and meaningful to study how teaching style directly influences student learning outcomes. This cognitive view is in contrast to earlier behavioral views which gave birth to systematic instructional design approaches much like Tyler's rationale. According to Wittrock, in behavioral conceptions the environment, not the learner, determines the product of learning. Since teacher and behavioral objectives were part of this environment, this orientation led to accountability of teachers in one form or another. He goes on to point out that contingency management, performance contracting, self-paced modules and related techniques are all designed to bring the learner under the control of the teacher. Perhaps it is time for science educators to take another look at the cognitive movement and conceptualize our methods, materials and research on learning with the learner in mind. Similarly, the teacher's role here would be modified to include diagnostic behaviors used to determine the characteristics of learners that contribute to attention and motivation and thus influence science learning. As Rothkopf (1970) pointed out:

> You can lead a horse to water, but the only water that gets into his stomach is what he drinks. The proposition is simple. In most instructional situations what is learned depends largely on the activities of the student. It therefore behoves those interested in the scientific study of istruction to examine these activities, i.e. the drinking habits of students (p. 325).

In the past, science educators may have been overly concerned with those parts of the Tylerian rationale which consider the discipline, with its goals, objectives, materials, and methods and have spent too little time observing the "drinking habits" of students in science (Tyler's first step). Perhaps we have been remiss in reminding students, their parents, administrators and others that a major responsibility for learning anything rests with the learner and his attention and motivation. It may be that after a thorough analysis of the factors leading to the "failure of teachers and schools," among the things we <u>can</u> <u>do</u> is better influence the "drinking habits" of students.

Gagnes (1980) work on problem-solving is consistent with the above cognitive conception of instruction and sheds some light on the way to approach changing goals and objectives. He points out that learning outcomes such as problem-solving and decision-making, among others (future desired goals according to Yager's work), strongly depend on how learners act on certain types of knowledge they already have available. (According to Yager's data science are already doing well in acquiring this knowledge.) Among the kinds of knowledge Gagne describes as critical are: (1) intellectual skills - "capabilities that make it possible for the individual to carry out procedures with symbols (as contrasted with procedures that employ bodily movement)"; (2) verbal knowledge - "knowledge of the world, specific and general, organized in various ways (e.g., names of objects, organized bodies of knowledge)"; (3) cognitive strategies - "capabilities that may control such processes as attention, perceiving, encoding, and retrieval of learned material as well as ways of thinking"; and (4) executive strategies - "enabling problem-solvers to weigh and choose the best strategy for the particular task."

His major point is that all of the experimental evidence indicates that these are learned capabilities, and in science some, if not all, are already part of existing instructional materials. It will take all kinds of background and knowledge to enable students to make the difficult environmental, bioethical, and biosocial decisions of the future. We should not overlook this and focus on superficial goals and objective changes without providing the underlying necessary knowledge base. My belief is that all students should achieve the above capabilities to some extent as part of their high school science experience. We cannot, and should not, short change one area of learning (for instance, verbal knowledge) and hope that students will be able to subsequently engage in more complex related behaviors. Nor should we settle for a different kind of science for the "non-science bound" student. Decision-making in the future will require a wide range of knowledge which all educated citizens should have at their disposal. The "scientist" should have this broad perspective to accompany his in-depth understanding of one discipline. But nonscience students surely need experience with verbal knowledge, intellectual skills, and cognitive strategies in biology, chemistry, and physics merely to take part in the future.

We must be careful not to weigh one kind of knowledge too heavily over others, or redesign curricula merely to include outcomes which the old curriculum may well be achieving, or for students who refuse to take responsibility for their own learning. The responsibility for many of the outcomes we wish for the student of the 80s still lies with that student and his "drinking habits." Only the student can analyze, synthesize, apply, decide, or solve problems. Previously acquired verbal knowledge, intellectual skills, cognitive strategies, and executive strategies form the basis for this behavior. Methods can be devised to get him/her to that point one-step-at-a-time. But all of the steps are essential for all students because they are going to be confronted with the same future!

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## SOME THOUGHTS

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### A TYLERIAN APPROACH TO SCIENCE EDUCATION

I find it difficult to react to Louis Rubin's chapter. He discusses Ralph Tyler's rationale for curriculum development, and I find myself unethusiastically agreeing with his approach. Rubin then seems to move away from curriculum to describe the gifted or artistic teacher. His descriptions are challenging, even exciting, and set a standard for teachers to attempt to reach.

Rubin then presents to a rather discouraging portrayal of the changes that are taking place in society, describing situations which the classroom teacher meets every day. He says, "It becomes necessary to re-think the dominant instructional responsibilities of the school." We realize that each day we open the classroom door.

### THE CURRENT STATUS OF SCIENCE EDUCATION IN U.S. SECONDARY SCHOOLS

Robert Yager accurately describes the situation of science from 1950-1980, and, as a secondary teacher during these years, I believe he has done this well. He points out the lack of esteem that the school and the community have given to science in general during the 1970's and the problems that have arisen. He particularly emphasizes the fact that science teaching in the elementary and secondary schools has had for its goal the "development of basic knowledge for academic preparation". He points out that teachers teach from a textbook, and therefore the textbook plays an overbearing rôle in the "sciencing" that is experienced. His summarization of the actual and the desired states of science teaching is of much value to the individual science teacher.

### SCIENTIFIC LITERACY: THE DECISION IS OURS

Peter Rubba explores various definitions of scientific literacy, indicating that early definitions were very ambiguous, and ends with the definition of Victor Showalter et al., including ways that the dimensions of scientific literacy can be used.

He points out the tragically clear situation that we are a nation of scientific illiterates and asks the question as to why the situation should exist when the 1960s abounded in science curriculum development. He answers his own question by pointing out that "the science curriculum efforts of the 1960s had as their aim the cultivation and pre-college training of a pool of potential scientists, engineers, and technicians." He then points out a statement of instructional objectives as developed by Hungerford and Tomera, and arrives at suggestions for textbook evaluation involving a numerical rating scale for the instructional objectives as presented by the text.

Certainly very little attention has been paid to citizen scientific literacy, and textbooks are often selected for frivolous or vain reasons. Professor Rubba clearly makes these points. However, textbooks and/or curriculum selection methods are going to be difficult to change, and the science teacher may never be able to make these changes unless he has practical, concise, down to-earth suggestions and/or directions for state departments of education and/or science education departments at the university level.

## BUT ........IT DOESN'T WORK FOR ME

Carl Berger's vignettes of fictitious teachers allow us to look at ourselves and suggest that each of us is a little like each of these teachers. I particularly liked his statement "ask not for who the curriculum tolls, it tolls for thee." While we must prepare our students using a variety of teaching styles and problem solving approaches, "...we must be challenged by our teaching in order to survive as teachers. In short, teaching must be fun for us."

## HOW TO MAKE IT FUN FOR KIDS

Paul Beisenherz's discussion of motiviation touches the most serious problem that I see in secondary education today. I have taught science in a small southern Indiana high school for 30 plus years and have experienced the entire spectrum of motivation from students. I recognize that ability is important (we say in the teachers' lounge "nothing beats brains") but the desire TO DO many times outshadows ability.

The desire TO DO comes from many sources: parental enthusiasm, competition with peers; a natural want-to-know attitude; and sometimes from teacher inducement. The desire TO DO is at its zenith in elementary school; wanes fast in middle school; and, usually, has been eclipsed in high school. For many, it is "not cool" to be motivated - to have the desire TO DO in high school.

Part of the blame for the lack of motivation must be accepted by the high school teacher. He is not enthusiastic enough about what he teaches. He needs a T-shirt which reads "Get High on Chemistry" and to live the part. But the school administration has assigned him too many classes with too many kids, with deadlines to meet, and the community expects the basics to be taught in a very concise, dignified, unimaginative manner.

What can the teacher do? Get excited about what you are teaching. Read Paul Beisenherz's chapter with an open mind and try some new approaches. They just might work.

## WHY AREN'T WE DOING IT?

J. Dudley Herron contends that "most of us only teach half as good as we know how." Then he enumerates the reasons for his question "Why aren't we doing better?" His reasons are correct, and, as a teacher for many years, I think I have justified my failures in teaching with each of Herron's reasons. I agree that parents have little direct knowledge of what happens to the child at school. I agree that grade inflation avoids problems, that textbooks are the curriculum, and that publishing companies are profit-making corporations.

However, Dr. Herron's suggested solutions for the problems may be ridiculous. He suggests that we put a teacher on a school board with voting privileges. School boards would go into shock, unless they could have an outstanding basketball or football coach who never talks with the rest of the faculty. He suggests that we let teachers have the power to remove the principal. To school administrators this would be akin to heresy. I agree with Dr. Herron's assessment of building principals, but to allow teachers to remove the principal by a vote of no-confidence would upset the system. The principal's position depends on quiet halls, quiet classrooms, good attendance records, and good fiscal accounting. Many are not interested in good education, especially if good education happens to be noisy.

To be sure, I agree with each one of Professor Herron's suggestions. I do not see how they can be implemented. But they have caused me - as a teacher - to stop and think about the system and to consider ways that I can improve science teaching. That is probably what Professor Herron was trying to get me to do all along.

## ONE STEP AT A TIME, BUT PLEASE HURRY

Dr. Andersen's interesting article raises the personal question, "Am I a semi-retired has been?" Or, am I still continuing to motivate learners? All science teachers should ask themselves this question and begin to take steps to improve their ability to motivate.

It is appropriate to start with the interests of students, and to remember that interest may fall in many dimensions, then to expand to contemporary life out of school, and then to go to subject matter specialists as a source of objectives. The teacher needs to look critically at his methods for reaching the objectives. It is difficult for the teacher to evaluate himself, but Dr. Andersen points out ways that this may be done. None of these methods will work perfectly, but a combination of several evaluations may allow the teacher "to see himself as others see him." Then the teacher must attempt to bring about needed changes. Certainly it is important to remember that "teaching is a complex activity that can be developed one step at a time."

ACHIEVING SCIENTIFIC LITERACY THROUGH CONTINUING EDUCATION

Hurrah for Prisk and Staver! They have written and quoted to point out effectively that we must design science programs to develop a scientifically literate citizenry, and that we must continue to educate -- especially, we must continue to educate science teachers. Let us go about the business of developing science courses that are useful to a wide range for individuals. Let us involve teachers and administrators with science education that is appropriate in their areas. Let us make it easier for science teachers to talk to each other and to college faculty. Let us use our science facilities for the continuing education for the adults in our communities. I agree, "we cannot afford to procrastinate."

# WHAT CAN BE DONE ABOUT TEACHER ATTITUDES?

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Upon completing the reading of the chapters to be included in the 1982 AETS Yearbook, my initial reaction was one of satisfaction and respect for the authors and their respective statements. Satisfaction stemmed from the knowledge and insights gained by reading the thoughtfully developed statements that characterized science education in the U.S. secondary schools. Respect was generated through an understanding of the time and effort necessary for the authors to prepare each chapter. My overall reaction is one of knowing that anyone interested in secondary science education will benefit from reading this yearbook. The information and suggestions presented will provide science educators with abundant "food for thought" as we search for solutions to the dilemmas facing the profession.

Rather than focus my remarks on chapters within the yearbook, I now would like to address an area not specifically mentioned. The area of concern is one that, I believe, is critical to any proposed solution to improving the teaching of science in our secondary schools. The concern is one of attitudes - expressed or imagined - toward the teaching profession in general and science teachers in particular; attitudes perceived by science teachers as they view their position in the community and the rewards associated with being an educator. When local and national leaders publicly call for budget cuts to hold the line on taxes, and science teachers see their instructional budgets reduced and salary increases not even keeping up with inflation, it becomes very difficult to maintain a positive attitude toward the profession. Parallel with the tax reduction issue, science teachers are painfully aware of the gap between teacher salaries and salaries for similarly trained people in the private sector. Thus, the economics of being a science teacher becomes a very important factor that must be addressed if lasting solutions to (as Yager cites) the crisis in science education are to be found.

In the chapter by Louis Rubin, the Tylerian approach to curriculum development is described. While I agree that it is essentially a process for identifying instructional objectives and that the model certainly offers a constructive approach to curriculum decision-making, it also assumes that certain resources are available: time and money. Given the current political and economic climates, I am not overly optimistic that either is available in sufficient quantities to make a significant impact on the problem. From my perspective, as budget reductions (cuts) are contemplated by public school adminstrators and boards of education, the area of support services is one of the first areas examined. Those services in the public schools that have (or had) the function of providing staff development and curriculum development responsibilities are examples.

Other economic ramifications can be enumerated to illustrate the magnitude of the problem. As budget reductions occur, eventually the impact is felt directly in the classroom. The effect usually shows up as an increase in the pupil-teacher ratio or class size. One only has to browse the literature to understand the heated debate over class size and student achievement. But that is another story. Another related economic issue is the ability of the profession to attract talented individuals to pursue science teaching careers. Of equal importance and personal concern is the prospect of retaining the competent and experienced science teachers already in the classroom. After limited public school resources are expended to improve the instructional capabilities of science teaching staff, they leave the profession for more lucrative positions. Teachers make such moves, not necessarily because they dislike teaching, but rather to gain financial security or to gain respect for their intellectual capabilities.

The economic factor also makes an impact on the science instructional program through the costs of constructing laboratory facilities. Questions are being raised as to whether or not the costs of science laboratory facilities can be justified on the basis of improved student achievement. As science educators, we are aware that the evidence is not clear in regard to that issue. Researchers have suggested that maybe the right questions are not being asked about the role science laboratory experiences play in student achievement. While I tend to agree with this position, I doubt that the general public would understand the debate. Also, when one considers the research described by Carl Berger on learning styles, the evidence becomes even less clear.

In the chapter by J. Dudley Herron, "Why Aren't We Doing It?" he suggests that science teachers are teaching only half as "good" as we know how. Why don't we do better? After listing some reasons for failure, he states, "It would be irresponsible to outline problems without suggesting the direction to be taken for solutions." Six suggestions are then given to help improve science teaching.

The suggestions may not have been made to address my concern about the "attitude problem" that currently detracts from our ability to resolve the crisis in science education. But suggestions five and six just might represent the type of creative and forward-looking ideas needed to build positive attitudes among science teachers. In addition, I believe all science educators must collectively and individually address economic issues of entering and remaining in the science teaching profession. Creative ideas are needed to encourage our talented and experienced science teachers to remain in the teaching profession. One such idea has been recently discussed by the executive committee of the Science Teachers Association of Texas. The idea centers around the establishment of an endowment fund supported by scientifically related businesses and industries. The proceeds from this fund would be used to supplement the salary of the recipient of a proposed Science Teaching Excellence Award. The general idea is to pattern this endowment fund and salary supplement after similar efforts at the college or university level. Ideally, the supplement could be substantial - several thousands of dollars.

The challenges facing secondary science education in the U.S. are many and varied. Determining what curricular changes are needed, developing instructional strategies that reflect pedagogical reserach findings, and offering worthwhile opportunities for continuing education are but a few of the problems confronting secondary science education. The reader can probably add several more. However, it is still the teacher in the classroom that makes it all work. The attitudes brought to the classroom situation will be reflected in the instructional program and eventually in the way students fell about science and science teaching. It is therefore incumbent on all science educators to work toward making the science teachers attitude as positive as possible.

## SOME REACTIONS

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### A TYLERIAN APPROACH TO SCIENCE EDUCATION

In the summer of 1964 I completed a valuable course at Indiana University with respect to science education. I had the opportunity to ask the guest lecture this question during an informal conversation: "This coming September, what should I teach six classes for fifth and sixth grade science students?" His reply was, "You know just as much about it as anyone." He was not referring to any wealth of knowledge about science curricula I might have; he was simply saying no one knows what to teach in elementary science. Is Louis Rubin saying that after 17 years we still do not know? I disagree.

There have been wonderful changes in education. Special education has removed the very mentally handicapped from the regular classroom. Learning disability teachers are expertly working with their students. We even have counselors in some elementary schools. All that development of the 1960s which resulted in works such as Elementary Science Studies can still be used. Middle schools are having science materials developed especially for them. This has given classroom teachers more time for perceptive understanding of their students.

The challenge of curriculum planning will always be an interesting part of education. A simple plan still seems to be elusive.

### THE CURRENT STATUS OF SCIENCE EDUCATION IN U.S. SECONDARY SCHOOLS

This chapter provides the reader a good historical review of the past three decades of science education. Is is hoped that the best of these curriculum plans will be incorporated in new plans for improving science education.

In looking to the future decade, Dr. Yager lists new general objectives for science education. The second of these includes the statement, "The new curricula should include components of science not currently defined and/or used in school. Direct student experiences, technology, and personal and societal concerns should be foci." This idea will cause thoughtful teachers to look carefully at lesson plans for science.

The most significant statement of this report seems to be in item three of the set of imperatives, "Without attention to in-service education, new directions and new views of the curriculum cannot succeed." Combine this statement with a sentence from item five, "Separation of researcher from practitioner is a major problem in science education: all facets of the profession must work in concert for major progress to occur." How can this be accomplished? It does not seem to be impossible, just puzzling at the moment of writing.

## SCIENTIFIC LITERACY: THE DECISION IS OURS

Peter Rubba gives a very thorough review of the definition of scientific literacy. In the middle school classroom, overcoming fear of natural phenomena, superstition, and ignorance of the laws of the universe is part of many extemporaneous class discussions. A review of the many aspects of scientific literacy is imperative for a teacher.

In the synopsis of his chapter, Rubba reinforces the importance of textbook selection methods. It has been my experience that an entire textbook committee can make mistakes. Here is a problem - how can a teacher select a textbook within a minimum amount of time? Could the objectives, goals, philosophy of the teacher be already worked out in curriculum planning? The teacher then would be willing to add or delete as experience or research indicates a need for goal changes. When the textbook selection is beyond control of an individual teacher, then problem-solving abilities learned in science studies are advantageous in working out a course plan.

Curricula based upon the goal of citizen scientific literacy as stated in the final paragraph of the synopsis will require more work. Cooperation will be needed from all aspects of the school community for this endeavor.

## BUT......IT DOESN'T WORK FOR ME

Reading Carl Berger's report should be encouraging to a creative science teacher. There is much to be studied in Berger's ideas. This chapter seems to confirm by research what many teachers know through experience--that teachers have individual styles of teaching and that students learn in different ways. The idea that conformity to a particular style of teaching is not necessary for success and that perhaps the most successful teacher moves from one style to another with ease is a statement of confidence. Administrators evaluating teacher performance should find this very important.

The teacher's role is to guide students to try different styles of learning, but to allow a student to adapt or place a concept in the most comfortable quadrant of understanding is a planning challenge. Individualizing instruction becomes difficult for middle-school teachers with large classes. This is where planning lessons over a grading period with grades given for reports, speeches, drawings, experiments, library research, and tests helps. Something for everyone is the exciting part of planning a course that works.

## HOW TO MAKE IT FUN FOR KIDS

Does Paul Beisenherz really have evidence that students are not turned on to science? Could it be that teachers are not turned on to science? Is there any research about motivating special education students through science studies? These questions were a reaction to this article.

The answers to the above questions seem to be found in statements such as, "Motivation comes back to needs and interests of the student. Curricula must be developed on your own." The author states that the personality of the teacher influences modes of teaching and philosophy. The importance of this article in telling how to make it fun for kids seems to focus on the idea that intrinsic motivation for the student comes from the intrinsic motivation of the teacher. The teacher needs to have fun, too.

## WHY AREN'T WE DOING IT

J. Dudley Herron has written a very perceptive chapter. The ultimate of impossibility was expressed one generation ago by saying, "You can't do that any more than you can fly to the moon." Well, we have flown to the moon. Perhaps this chapter is not as impossible as it sounds. The problem is very accurately stated. Although I would not minimize the other facets of school problems, the item of textbooks is particularly important to me. After spending many hours evaluating sixth grade science texts last year, I realized how often publishers disregarded research in education. Many of the texts were not written for students. They were published for teachers. They had one theme: how easily you could plan 15 or even 30 minutes of something called science in a day's busy schedule. Who <u>can</u> solve the problem of textbooks? Where do you begin?

Item five of this chapter is a mind-expanding plan. How does the school system choose the representative on the school board? When during the school year would the faculty hold a vote of confidence in the principal? Who is going to "chair" the research and statistics committee? These things are not impossible. It is the observation that the soldier (or teacher) on the front line does not have time to do research on the best kind of ammunition. You just fire away with what you have. Somehow this expertise of front line experience must be used to solve problems.

## ONE STEP AT A TIME, BUT PLEASE HURRY

This chapter by Andersen puts local curriculum planning directly in the work of the creative teacher. One question that seems to be significant is, What is student interest? Is it understanding a typical student, or what the student is interested in studying? How much classroom time should be used looking into interests? The students in a particular class are there because that time period fits their schedule. They are not grouped according to their aesthetic, historical, or tehnological interests. The proposal then must be to expose all students to all interests and then let them excel where their maturing judgement leads. There are students who tell an elementary teacher, "The only thing I will study is animals; I do not like the rest of this stuff." or, "You know I do not like nature walks." This is when teaching becomes a psychological skill. The teacher certainly can consider interests, but balance is necessary and the complexities must be evaluated.

The subject matter of an elementary science curriculum in southern Indiana may differ considerably from studies in the northern part of the state. Contempory life must be considered, but the process of science does not change nor do the psychological problems of learning in either situation. As to philosophy, it seems to be needed as an underlying attitude, pulling together isolated ideas. But problems could arise if it becomes dogmatic.

Curriculum planning along with teacher strategy, is a very complex activity, as Dr. Andersen states. It is hoped that the student, the teacher, and the researcher will continue to search for improvements. It is encouraging to read this may be done "one step at a time."

## ACHIEVING SCIENTIFIC LITERACY THROUGH CONTINUING EDUCATION

There are prodigious mental pictures in this chapter. Continuing education is a beautiful, elegant idea. This is a most refreshing, encouraging report on ways to communicate for all concerned about science education.