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ABSTRACT

Included in this record of the proceedings of the eighth annual conference of the Federation for Unified Science Education (FUSE) are texts of major presentations, panel discussions, and contributed papers. Other activities of the conference are also reported. (CP)

"Unified Science - Premises and Prospects"

Proceedings of the

Eighth Annual Conference
of the Federation for Unified Science Education (FUSE)

May 2-5, 1974

Edited by

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October, 1975

Preface to the Conference

The Federation for Unified Science Education (FUSE) has conducted annual self-supporting conferences since the group's inception in 1966. Although the conference reported herein is the eighth in the series, it is the first for which a comprehensive report of the proceedings has been published.

The whole idea of unified science - to base school science programs on ideas, processes, etc., that transcend the specialized sciences - has arisen from a grass/roots base. For that reason, various "forms" of unified science have developed in individual schools. Thus, there is not one particular unified science program nor a single set of instructional materials that can reflect accurately the philosophy and rationale for school science that permeates a FUSE Conference.

The concept of unified science is still evolving and infuses a conference such as this with an atmosphere of creativity, portent, and open-endedness. Thus, the FUSE conference structure is relatively open with many opportunities for participants to question, rebut, and discuss each presentation. Some of the substance of these discussions is reported in the summaries of panel discussions and contributed papers.

The Theme

It is the hope of the editors that the theme of the conference, "Unified Science - Premises and Prospects," represents a topic and frontier as exciting to other readers concerned with science education as it was to the participants in the conference itself.

The theme itself was chosen because it reflects two persistent concerns that are part of the spirit of unified science. First, there is the concern that the premises or foundations of unified science must be reviewed periodically so that well considered evolution of the concept may occur and that practitioners of unified science may be renewed in their own efforts and that newcomers to unified science may find their own inspiration for future option.

The premises of unified science involve: the nature of science, the nature of learners and learning, and the goals of science teaching.

The second aspect of the theme, that of "promises," implies the future tasks and rewards demanded of and available to learners and teachers who are involved in unified science.

Since unified science and its practitioners are a type of educational minority in the United States and the world, the FUSE conferences have always provided the participants with renewed enthusiasm for their efforts. This is especially crucial for those who teach in communities surrounded by educational conventionalism.

The Terminology

In order to facilitate communication among participants, a short glossary of crucial terminology was established by printing it in the official conference program. These terms were used more or less consistently throughout the conference and there has been an effort to extend that consistency to this publication. Items in the glossary:

> *"unified science"* will be taken to mean any planned curriculum in science in which the boundaries between the specialized sciences are minimized or dissolved in favor of certain characteristics that transcend the specialized sciences.
>
> *"program"* will be taken to mean a planned curriculum that continues over an extended period of time as three, four, six, or twelve years.
>
> *"unit"* will be taken to mean an organizational component in a science program. It might run two, four, six, nine, or twelve weeks.
>
> *"module"* will be taken to mean a more-or-less self-contained segment of learning activity that is smaller than a unit and is a part of a unit.
>
> *"concept"* will be taken to mean a general idea or understanding usually symbolized by a single word such as energy, organism, etc.

<u>The Workshop</u>

The addition of a Thursday workshop to what had been basically a Friday-Saturday format was a departure from previous years. The response to this innovation may well justify its inclusion in subsequent FUSE conferences.

The workshop concentrated on the rationale and techniques of one specific unified science approach to curriculum development. This particular approach has become labeled the "modular unit" technique. This is the approach advocated by the Center for Unified Science Education and is detailed in the "workshop" section of this document. A brief history of the Center for Unified Science Education and its relationship to FUSE occurs in "Unified Science Education Today and Tomorrow" which can be found in the "Major Presentation" section of these proceedings.

<u>The Speakers, Panelists, and Participants</u>

The people who made major presentations were invited to do so because of their previous identification with philosophical ideas that seemed to be consonant with those which comprise the basic premises of unified science. Most of these people had not been associated with FUSE activities previously and thus were able to contribute fresh ideas to new acquaintances but who were not strangers to the concerns reflected in the presentations.

Several panelists, especially those from Ohio State University who participated in the concurrent "concept" panels, were new to FUSE activities. Many, if not most, of these individuals work within one of the specialized sciences. Their participation is <u>not</u> inconsistent with unified science premises since the value of the specialized sciences <u>for specialized scientists</u> is acknowledged by FUSE people.

Although the concept of unified science is applicable at all grade levels, most participants were secondary teachers, college level teachers, or curriculum supervisors. Although many K-6 teachers have participated in the development of unified science programs, they have not participated to any great extent in this or previous FUSE conferences.

Many, if not most, of the secondary school participants have been and/or are currently involved in some type of unified science curriculum development.

Concept Panels

The centrality of science concepts in any unified science approach to curriculum development was the reason for establishing the panels on selected concepts. The basic purpose of these sessions was to expand each participant's understanding of the specific concepts discussed. As a matter of fact, several of the panelists themselves expressed a surprising interest to learn that concepts which they had assumed were "private property" were in fact so universal.

The Tours

A tradition has developed during the relatively short history of FUSE that each conference should include classroom visitation of an ongoing unified science program. This conference continues the tradition in the belief that doing so gives conference participants a broader perspective of unified science and also a common base of experience for subsequent discussion.

One of the premises that seems to underlie most unified science programs is the belief that local resources should form a significant and integral part of the science program. The classroom visitation along with the other tours are intended to reinforce this particular premise as well as contribute in the more obvious ways to the success of the conference.

The Editing

The task of editing these proceedings was complicated by the fact that much of the original material was in the form of tape recordings, some of which were of marginal audibility. The editors have made every effort to report accurately the sense of the various discussions and those contributed papers that are presented here as abstracts. The major presentations and the full scale contributed papers have been reproduced directly from the originals with only very minor editorial change.

Because everyone involved in preparing these proceedings has been employed full-time on other specific endeavors, the time-lag between the actual conference and the publication of these proceedings has been greater than desired. Nevertheless, there is reason to believe that interest in and timeliness of the contents have not suffered unduly by the extended passage of time.

The editors, at the time these proceedings were prepared, were all associated with the Center for Unified Science Education.

The Art

The patterns on the cover and interspersed throughout the book are intended to be more than graphic decoration. As a group, they symbolize the variety of external forms that are possible given the same basic ingredients. As with the variety of unique unified science programs, a single set of basic beliefs and dynamic techniques can lead to a myriad of external expressions.

For the technically inclined, the patterns were produced by a commercially available device called a "Gizmo." Essentially, two pendulums are coupled to a single point which is a tracing point. The angle between the plane of the pendulums is nominally ninety degrees. The patterns are generated by gradual damping of the resultant movement at the point of connection.

Acknowledgements

The conference program was planned and publicized by the editors of these proceedings. Our efforts would have been futile except for the great assistance of Dana Willard who is more than the secretary of the Center for Unified Science Education. The faculty and graduate students of Science and Mathematics Education of The Ohio State University also are to be commended for their valuable help.

Victor Showalter
Center for Unified Science Education
Ohio State University
Columbus, Ohio
September, 1975

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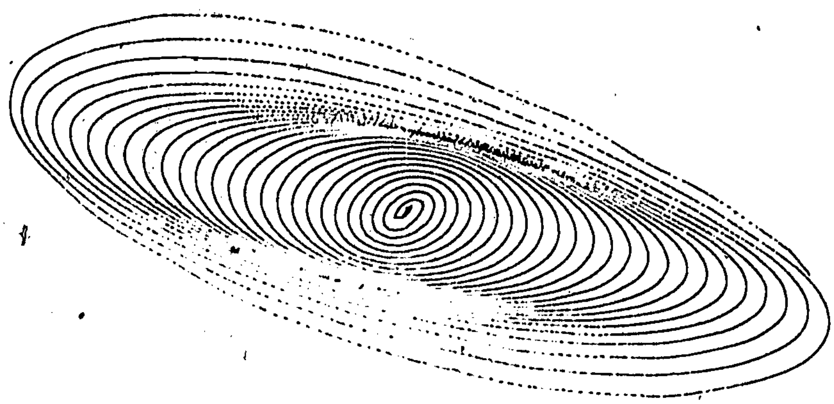

Notes on "Theoretical Foundations for Unified Science Education"

by Philip H. Phenix

Dr. Philip H. Phenix is currently Arthur I. Gates Professor of Philosophy and Education, Teachers College, Columbia University. He was born in Denver, Colorado, in 1915. He received his B.A. (summa cum laude) in mathematical physics from Princeton in 1934. In 1942 he graduated in theology from Union Theological Seminary. He received his Ph.D. in philosophy of religion from Columbia University.

He has special professional interests in the theory of knowledge and in moral and religious philosophy. Among his many publications are: Realms of Meaning (McGraw-Hill, 1964) and Education and the Common Good (Harper, 1961).

My aim: to suggest some theoretical bases for unified science education. Showing some of the complex issues of epistemology and social psychology.

Some causes of the movement toward unified science curriculum:

1. The multiplication of specialties. Too many to handle!
2. Limitations of time in the curriculum. How choose which to teach?
3. The unpopularity of science with many students. "Inhumane"
4. New emphasis on humanistic and affective education.
5. The rise of "hyphenated" sciences, e.g., astro-physics, psychological anthropology.
6. The problem approach to inquiry and education, e.g., ecology, war.
7. Science development breaking its bonds by its own internal logic.
8. Scientists, science teachers, and students with wide interests.

Doubtless there is a place for both special sciences and for unified science.

The question: Where does each belong, and why? What <u>is</u> unified science?

The obvious tentative answer:

a. Unified science in general education.
b. Specialized science in professional education.

But this answer may not suffice, since!

a. General education will not be served by a confused melange of general science. It may be better to offer specialized sciences, with student choice.
b. Professional science education may well require unified science perspective.

Hence, we are driven to look at the question of unified science in its theoretical bases.

<u>Special Science vs. Unified Science: A dialectical relation</u>

There are values both in specialization and unification. In creative tension, I shall deal with eight aspects of this dialectic.

1. Progress vs. Extinction

Historically, specialization has been associated with great progress in science.

Successive special sciences have split off from philosophy, as a comprehensive wisdom.

Aristotelian science was notably sterile.

Don't go back to the speculative morass of the pre-scientific age!

Remember August Comte's stages: from theology to philosophy to science.

But there's trouble whenever a discipline loses contact with its roots.

The cut flower phenomenon.

Buckminster Fuller: Excessive specialization leads to extinction.

The future lies with those who are capable of wide generalization.

Is the old intuition of the unity of knowledge a valuable one?

2. Depth vs. Comprehension

Only by specializing can one go deeply into an area of experience.

General study remains on a superficial level.

Rigorous exclusion of extraneous material required. Limit scope of inquiry.

But this depth is bought at the price of breadth.

One knows more and more about less and less. Is it worthwhile?

It is even doubtful that narrow knowledge is really deep.

Perhaps depth is dependent on wider relations.

3. Clarity vs. Distortion

Clarity of definition requires simplifying models and assumptions.

e.g., mathematical models of physics or economics, "ideal" constructs like frictionless planes, perfect competition.

These concepts define the specialty.

But abstractions are artificial. They eliminate part of the truth.

Hence all model making is distorting, hides as well as reveals.

Every category in a specialty is a deliberate construct, a creature of the inquirer.

These are subject to change and modification, to choice of alternatives.

Unifiers stress the voluntary nature of model and category formation.

4. Tradition vs. Innovation

Specialization requires a secure tradition, with clear definitions.

This is the basis for training new members of the discipline.

Science ordinarily proceeds by the elaboration of the standard tradition.

See Thomas S. Kuhn, The Structure of Scientific Revolutions.

"Normal science" based on textbook tradition.

Science requires discipline, rigor, obedience to the canons of the field.

But such discipline may stand in the way of innovation.

Kuhn's "revolutionary science" requires fresh insights from beyond the specialty.

History of science shows the need for new paradigms.

Revolutionaries are heretical, do not follow the textbook models.

Only those with wider insights are able to devise new concepts and models.

e.g., field theories in psychology and sociology, atomism in biology, historical concepts needed in physical cosmology.

Innovation as a process of hybridization.

cf., the profound analysis in H.G. Barnett, Innovation: The Basis of Cultural Change.

Much of the literature on the process of invention, creative thinking, etc.

stresses crossing of discipline ideas.

e.g., "brainstorming," "synectics," "lateral thinking."

Use of analogies.

5. Objectivity vs. Intersubjectivity

Science is objective truth. Value-free.

It must remain pure, free of application pressures and constraints.

Science students must not be concerned about the uses to which knowledge is put.

But scientists are increasingly aware of their social responsibilities.

Science has its values. It depends on social support.

See Michael Polanyi, Personal Knowledge. The "conviviality" of the scientific community.

Thus it is essential to consider the wider relations of science disciplines.

6. Closed vs. Open

Specialization breeds espirit de corps.

The members of a discipline are a close-knit group of insiders, initiates.

They appeal to a special language, jealously guard their domain.

But one needs to communicate with others to be understood in the wider community.

Is there a lingua franca of science? How interpret it to those whose interest and support may be required?

The riches of others' experience and insight must be opened up.

7. One Talent vs. Whole Person

Specialism appeals to the person who feels unable to handle very complex problems.

The ordinary person requires the security of a limited, familiar domain.

Do one thing at a time! Divide and conquer.

But persons are whole. Life cannot be split up into independent compartments.

How aid students in gaining an integrated view of life and knowledge?

Everyone acts as a whole and not segmentally.

Unified science is grounded in the wholeness of personality.

8. Elite vs. Commonwealth

There is cash value in the prestige of science.
So don't mix up with humanities and social studies.
There is great advantage in remaining separate, at the pinnacle of knowledge.
But there is a new strong concern for human meaning, challenging the old hierarchies.
In the end, it is better for all scholars and teachers to see their common task.
It is particularly important to see science as one of the great achievements of the human mind and spirit.

Metaphysical Considerations

What metaphysics is, in this context:
Not speculation about a supersensible realm, beyond experience.
It means the study of the most general categories for interpreting anything at all. e.g., thing, event, quality.
Now some metaphysics is necessary for any rational discourse.
There must be terms for dealing with the world as intelligible.
All discourse presupposes some world-view.

A radical specializer denies this necessity.
He appeals only to terms required within his discipline.
But he nevertheless has an implicit world-view which he assumes without examination.
The dogmatic positivist is anti-metaphysical.
But only at the cost of dismissing from rational scrutiny large areas of experience. e.g., moral, aesthetic, religious.

Recognizing this need for a general world-view supports unified science aims.
It challenges the total compartmentalizing of the disciplines.
The general categories allow one to relate disciplines to one another.
They also point to the ultimate unity of all knowledge.
And for a view of the curriculum as a whole.

See Stephen Pepper's World Hypotheses for valuable suggestions on the metaphysical problem.
He develops the notion of "root metaphors" as the basis for world hypotheses.

Pepper identifies four about equally acceptable world hypotheses:
1. Formism (root metaphor similarity). Classical realism an example.
2. Mechanism (root metaphor machine). Naturalism an example.
3. Contextualism (root metaphor event). Pragmatism an example.
4. Organism (root metaphor maturation process). Absolute idealism an example.

Each world hypothesis has its shortcomings, either of precision or scope, but also strong arguments in its favor.
In practice, not in theory, an eclecticism is the best one can hope for.

It is a useful exercise to apply each of these world hypotheses to set up a view of unified science.

The Aristotelian view of science was formistic: classes, categories, loosely related.
Mechanism is the most usual system for science, e.g., a unified field theory.
But the problem is what to do about mind. How integrate man and society with nature?
Bridgman's operationalism was a contextual basis for unified science.
But this tends to be dispersive, like formism too loosely articulated.
Teilhard de Chardin's organismic view of science unites mind and matter, but leaves unsolved some problems of how to interpret time and change.

Such world hypotheses are useful not only as a basis for unified science, but also for all other disciplines and for handling the relationships among the several disciplines in the sciences, social studies, and humanities.

My Suggested Framework for Discipline Analysis
I have developed a scheme for interrelating the various disciplines, both scientific and other, in my work Realms of Meaning.

This is based on an inductive analysis of the actual procedures in the disciplines.
The result is a pattern of 9 basic logical possibilities, as follows:

1. Symbolics (language and mathematics): General Form
2. Empirics (the sciences): General Fact
3. Aesthetics (the arts): Singular Form
4. Synnoetics (personal knowledge): Singular Fact
5. Ethics of situation: Singular Norm
6. Ethics of rule: General Norm
7. History: Comprehensive Fact
8. Religion: Comprehensive Norm
9. Philosophy: Comprehensive Norm

It may be useful to re-interpret these patterns by means of an analysis of "elements" and "modes" in the disciplines, as follows:

Elements	Modes
Pattern Making	Concentrating (Pluralistic tendency)
Truth Seeking	Abstracting (Monistic tendency)
Prizing	Integrating (Dialectic tendency)

Each element and each mode represents a basic cognitive activity to be mastered.
These are the ingredients in all cognitive inquiry.
Every discipline is a particular mix and weighting of these elements and modes.
All are present in every discipline, but with different weights.

The basic tasks of the several discipline groups are as follows:

Pattern Making: Arts for the pluralistic mode
Language and mathematics for the monistic mode
Philosophy for the dialectic mode

Truth Seeking: Synnoetics for the pluralistic mode
Science for the monistic mode
History for the dialectic mode

Prizing: Problematics for the pluralistic mode
Normative Ethics for the monistic mode
Religion for the dialectic mode

Although these are basic tasks, each discipline group also makes use of the other elements and modes, as the following examples suggest:

Physics has important dimensions of pattern making, in its use of models.
This suggests the value of relating physical science to the insights of the arts, to philosophy, and to mathematics, all of which are concerned with pattern making.

Biology requires the pattern making activity of language in its taxonomic aspects, historical considerations in its evolutionary theory, synnoetics in considering the process of individuation, and religion in connection with questions of ultimate cosmic development and orthogenesis.

Economics makes use of mathematical models, decision techniques of problematics, and the ethics of public policy.

Anthropology includes synnoetic concerns for particular cultures, the values of social norms, and the comprehensive orientations of religion.

Psychology relates to synnoetic considerations of personal uniqueness and to problems of religion in relation to creativity, imagination, symbolization, etc.

Geography utilizes the arts of mapping, the problematics of resource distribution and use, and the ethics of public policy in relation to demography, etc.

History employs the art of dramatic recounting, the philosophy of man, the synnoetics of the particular event, the generalizations of social science, the problematics of decision making, the values of ethic principle, and the religious insights about the meaning of the human career as a whole.

Such an approach shows that all inquirers are engaged in a common endeavor, but with different weighting of elements and modes.

All inquirers seek to answer these 6 great questions:

1. What interesting and useful structures can I design?
2. What is truth and how may my structures reveal it?
3. What is really worthwhile to make, to do, and to know?
4. What things are unique, new, and surprising?
5. What things show identities? How may they be grouped into classes?
6. What is the whole into which all things cohere?

"Science and Contemporary Problems"

by R. G. H. Siu

Dr. Ralph G. H. Siu is presently Chairman of the Members of the Academy for Contemporary Problems and a private consultant in executive strategy. He was born in Honolulu in 1917 and received both his B.S. and M.S. degrees from the University of Hawaii. His Ph.D. is in chemistry from the California Institute of Technology.

He has been specially interested in the application of Eastern philosophy to Western science. His books include: The Man of Many Qualities (MIT Press, 1968), The Tao of Science (MIT Press, 1958), and Microbial Decomposition of Cellulose with Special Reference to Cotton Textiles (Reinhold, 1951).

Introduction

Up until the last three decades or so, scientists as a group have not addressed themselves seriously to the question of personal responsibility in the application of knowledge. The general posture of the majority had been somewhat along the fatalism of the average man on the street, who says: "You can't stop progress." Society itself seemed resigned to ineffectual mastery over its destiny, as science and technology set new boundaries and injected new effects.

During the last decade or two, however, there has been increasing attention to the inseparability of science and contemporary problems. There seems to be mounting activity among scientists and engineers in political and social matters. We need not go into details to prove the point. We need only mention the various Committees of Scientists and Engineers in the recent presidential campaigns as illustrative of professional involvement in practical politics on a national scale, the Bulletin of Atomic Scientists as illustrative of their commitment to social affairs, and the award of a Nobel peace prize to a Nobel laureate in chemistry as illustrative of their successful venture on an international scale.

Overview

I suppose it was partly because of the timeliness of this subject of science and contemporary problems that your chairman, Dr. Victor Showalter, had asked me to speak to it.

My talk will be divided into three parts. First, the contributions of science to society. Second, the higher order effects of science and its impact on society. And third, a proposed post-graduate course in Unified Science Education in the light of these and other considerations.

Contributions of Science to Society

In discussing the contributions of science and technology, we usually take either one of two standard approaches. We may choose to extol the glorious creativity of science -- how science will usher in the

14-karat golden age of the triple-trillion-dollar GNP, of the elucidation of the salubrious secrets of sex, of the coupling of electronic devices to the human psyche, and so on.

Or we may choose to beat our breast over the pessimistic ramifications -- how science is to extricate man from his technological purgatory of pollution, depersonalization, mass killing, and other doom-and-glooms.

Either treatment would have led to interesting copy for lay audiences. But they are both old hat to you. So I will bypass such eulogizing and sermonizing. Instead, I will mention two examples, not so much to show the way in which science and technology can contribute to the solution of contemporary problems but to emphasize the necessity of close cooperation between the scientific and the other sectors of society before major social advances can be further realized.

Let us consider health as the first example. The contributions of medical science to health have been particularly impressive for the young since the turn of the century. The life expectancy rose from 47.3 years at that time to 70.5 in 1967. For some reason, however, further advances since 1957 have been disappointingly low. Men living in fifteen other countries have longer life expectancies than we do. Our relative ranking in infant mortality rates dropped from fifth in 1950 to about twelfth today. At least five countries enjoy better maternal mortality rates than we do. The question is why is it that just when medical science began making great strides in this country -- when Americans were being awarded Nobel prize after Nobel prize in medicine and when the national expenditure for medical research was being increased an order of magnitude exceeding the billion-dollars-per-year mark -- we began to lost relative health standing among the world societies? Whether the decrease in our relative health standing is due primarily to our changing life styles, to the uneven distribution of food and medical assistance, to the misdirected elements of American science and technology, or to what else is hard to say.

Our second example concerns municipal services. It shows the complicated ways in which a particular need for scientific assistance arises. The schools, the hospitals, the garbage collection, and the rest of the municipal services have been caught in a financial squeeze brought about in large part, although indirectly, through the contributions of science and technology in another sector of our technological society. When technology increased the productive capacity of our manufacturing industries, the cost of goods was drastically reduced and part of the savings was passed on to the employees in the form of increased wages. In order to be competitive, the wages of service personnel had to follow suit. Unfortunately, there was no product to absorb the increased cost. Furthermore, the manpower requirements per unit of service was actually going up with the years, instead of going down in many cases. For example, the public schools average ten per cent fewer students per teacher today than they did less than two decades ago. The cost per student in constant dollars almost doubled. The cost of hospitalization jumped twenty-two per cent in a single year between 1966 and 1967. There are far more private law-enforcement personnel by way of campus guards, store detectives, and the like today than there are public police, FBI agents, and the like. The question arises: What can science and technology do to slow down this burgeoning cost of municipal services?

Unfortunately, the glamor of research and development activities continues to be making reputations and making money on new concepts and new products rather than saving money on old-line services. So the urgent need remains. Unless scientific and technological ingenuity is directed effectively toward driving down the cost of municipal services drastically, their mounting financial appetites will destroy the large urban centers as harmonious communities, probably as fast as any other single inadequacy.

Higher Order Societal Effects

We can see from this that the contributions of science and technology are seldom unalloyed. Nearly always there are higher order societal effects accompanying the first order technological motivations. As Emerson had once said, "Nature never gives anything to anyone. Everything is sold." Some of the resulting higher order effects appear acceptable but others may not be so, if we actually recognize them for what they are.

The invention of farming, for example, not only provided a more continuous supply of food; which was the first order objectives, but also gave rise to a more stable society for the inhabitants and comfort for their aged. Previously, the nomadic herders and food gatherers had to roam far and wide. The old were frequently left behind to die as the survival of the small clans required their moving on in search of food.

As technological accomplishments led to directing the flow of energy from the wind to the sail in ships, men became capable of bringing food to others living where there was no food but where there was timber and of bringing timber to those living where there was no timber but where there was food. With this came new social relationships.

As societies became more technologically energy-dependent, professional specializations evolved. The extended family of former days was no longer capable of providing the minimum skills for a livelihood. The head of the family was no longer able to assign roles and responsibilities for the simple reason that the sustaining enterprise extended far beyond the confines of the family and clan. The younger members of the family must look elsewhere for expertise and support. The conjugal units move under the attractions of the high-energy processors.

Thus, it was that the decline in the social function of the family and in the social significance of the head of the household became a natural consequence. The dissolution of the family as a continuing cohesive unit became an inevitable higher order effect of a high-energy technology.

A Post-Graduate Course

Once we begin to be concerned about higher order effects, we find ourselves entering an exceedingly complicated realm, in which the available techniques of science and rationality itself are woefully inadequate. I would like to propose that a post-graduate course in unified science education be devoted to this realm.

The rest of our discussion will constitute a reconnoitering of the general orientation for such a course. In so doing, we will touch upon some of the facets of the requisite kind of enlightenment for effectively operating in that realm. We will be talking about the relevance of learning.

about multidisciplinary approaches, about Chinese baseball, about the instantaneous apprehension of the totality, and about the art of subsuming and resonating.

Relevance

We will begin with the relevance of learning. Since it was vociferously touted during the students' riots ten years or so ago, the term relevance has now become hackneyed. Yet it seems that the full implications of the term have not been generally appreciated. It may be well to clarify our own thinking on the matter.

One of the best points of departure is to distinguish the phrase "being *related* to" from the phrase "being *relevant* to." Being related to something is not necessarily being relevant to it.

Everything in the universe is related in one way or another to everything else. "If I move my hand," so the old saying goes, "the entire universe moves." The center of gravity is shifted and accordingly everything else adjusts an infinitesimal amount. In being related to something, pace is of no consequence; time is of no essence; timing is of no necessity.

Being relevant to something, however, entails a healing reciprocity, ameliorating the everchanging discrepancies between status and desire, between possessions and needs. When patience is running thin, the sense of reality needs to be more tangible to be relevant. When suffering is being endured, the sense of relief needs to be more significant to be relevant.

Everything that has been, is being, and will ever be cogitated upon by scholars is related to life in one way or another. But so what? -- society exclaims in existential anguish. This might have been the unarticulated meaning behind many a student's troubled indecisions regarding the course of his education and his dissatisfactions with the offerings of many a major. There are cogent reasons to believe that the central and unique character of great scholarship is not being intellectually and inspirationally related to mankind, so much as being perennially and penetratingly relevant to it, so that human beings can appreciate the substance and meaning of life while living it.

If perennial relevance is one of the principal criteria of great scholarship and if great scholarship is indeed the thrust of academic learning, then there are grounds to fear that the present campus arrangement of disciplines may not be optimal.

Multidisciplinary Approaches

The present arrangement of academic departments is geared primarily to the advancement of specialized knowledge within bounded disciplines. The limitations have been recognized by you and others for several decades. The polished manners of the traditional departments simply do not reflect the rustic ways of life. As a result, specialists from various departments have begun to pool their talents and come up with various alternatives to improve the situation. Much of the experimentation with unstructured learning, spontaneous expressiveness, consciousness stimulation, ghetto participation, black studies, and so on was directed toward this end of making the curriculum more expressly relevant to living.

The greatest effort has been directed toward the development of interdisicplinary or multidisciplinary teams. You are familiar with these attempts, so there is no need for an elaboration on their nature.

It has been my experience, however, that even in these multidisciplinary programs, the members continue to conceptualize segmented totalities in terms of their respective truncated specialties. Just as the students are being taught today, their professors had also been taught to conceive of reality as an accumulation of the viewpoints of specialists -- not so much from the explicit statements of the teachers but from the very arrangement of the educational structure itself. The outcomes of such multidisciplinary efforts on contemporary issues other than purely inanimate systems, more often than not, remain artificial nonviable composites of alternative force-fitted modules, instead of the desired alternative choices of viable feasibilities or actualities of organismic wholes.

The essence of a student riot, for example, can never be grasped in a multidisciplinary task force by listening to a theologian on the action of God's grace on men's lives, then to a physicist on the equations of force, then to an economist on the pressures of inflation, then to an attorney on the constitutionality of violence, then to a psychiatrist on the transactional analysis, and so on. The thousand and one, out of the infinite facets related to man, may be analyzed in the thousand and one academic specialties. But man cannot be appreciated in his reality and wholeness through this kind of endless repetitions of segmentations.

It would appear, therefore, that the popular multidisciplinary approach, although a major advance over the former compartmentalization, still has a long way to go before becoming capable of communicating the real condition of man. Reality does not recognize disciplines as conjured up by a committee of specialists still acting with the viewpoints of specialists. Reality must be understood on its own terms. Not only does it amalgamate conventional descriptions but it also fuses understanding and feeling, learning and doing, thinking and caring.

It is recognized that the educator must continue to live largely within the venerable traditions of the campus. Yet the pioneering educator must be aware of their limitations and move them gently toward increasingly meaningful relevance without destroying the equally important values that they have brought with them over the years. I have the feeling that your own approach to unified science education is moving in this direction of transforming the relatedness of conventional learning to the relevance of wholesome living.

But, as you have undoubtedly realized from your own experience, the path is not an easy one. There are many formidable conceptual obstacles, quite apart from the sheer inertia of society against change of any kind. One of the more challenging of these obstacles is the handling of change itself. This brings us to the game of Chinese baseball.

Chinese Baseball

If there is one principle that we should bear in mind in dealing with contemporary social problems, it is Chinese baseball. By the way, how many of you have ever played Chinese baseball?

Chinese baseball is played almost exactly like American baseball -- the same field, players, bats and balls, method of keeping score, and so on. The batter stands in the batter's box, as usual. The pitcher stands on the pitcher's mound, as usual. He winds up, as usual, and zips the ball down the alley. There is one and only one difference. And that is: *After the ball leaves the pitcher's hand and as long as the ball is in the air, anyone can move any of the bases anywhere.*

The real name of the game of living is Chinese baseball, rather than American baseball. It behooves us to learn it well if we are to deal effectively with contemporary problems. In other words, everything is changing all the time -- not only the events themselves but also the rules governing the events and the criteria of values. One must keep his eye not only on the fast-moving ball but also on the fast-shifting bases as well. American baseball, with its fixed bases of reference, is played only under certain specialized and controlled circumstances, in which the scientific method is so well suited. It is not representative of the usual social dilemmas.

Instantaneous Apprehension of the Totality

It is because of the recognition of this ever-changing feature of social reality, in part, that the old Taoist masters had identified the mark of the wise man as the instantaneous apprehension of the totality.

The key word in this phrase is "apprehension." The Taoist masters assert that reality is not portrayable in words. They would have little to do with mathematical modeling and analytical techniques as the prime basis for decisions affecting man. The essence of life is ineffable. They would place no faith in words and equations as the final arbiter of one's social choices. As the proverb goes, "The wise man does not speak; the talented man talks; the stupid man argues." Reality is grasped not through rationality and understanding but through apprehending, feeling, sensing, and such ineffable avenues -- like a person falling in love.

This brings to mind the important distinction between symbolic knowledge and intimate knowledge. A person with only symbolic knowledge but no intimate knowledge about humor, for example, is one who can tell you all about the difference between a pun and a conundrum, the names of all the great comedies ever played on Broadway, the antics of the jester in the court of Peter the Great, and so on and on, but he can't crack a joke himself.

When dealing with human issues, it is the person who can get things done rather than the one who can only explain why it cannot be done that we usually prefer. Generally, it is the person with the gut feeling rather than the one with the verbal explanation. Of course, there is always the complete person who can do both. Perhaps such gems of personality will come out of your post-graduate course in unified science education!

To be most effective, the person must respond instantaneously -- at the moment when it counts. Everything is to coalesce in the instant -- like a knock. When I knock on this table, the sound does not wait for an explanation of the impact before it issues forth. The impact and the sound, the cause and the effect, all occur in the instant.

Not only does the wise man apprehend things and events and apprehend them instantaneously, he also apprehends the context in which they are imbedded and that context is the totality. There is no need for me to repeat the story of the blind men and the elephant. Nor is there need to belabor the commonsense admonitions about seeing the big picture or getting the whole story. However, you may be interested in a comparative observation on the relative effectiveness between the so-called wholist strategy and the so-called partist strategy in solving problems.

The wholist strategy begins with the totality, so that all factors are included in the net of consideration. The strategy then successively eliminates unnecessary and less relevant components, until the desired equilibrium answer is reached. In this case, the answer at any given moment is always correct but with varying degrees of impurities.

In contrast, the partist strategy begins with an assumed collection of related factors as the cause. The strategy then successively tests different combinations and permutations of factors. In this case, the answer at any given moment is always precise but wrong, until the correct one is found.

Some preliminary experiments had actually been done some years ago in comparing the effectiveness of the two strategies in the solving of problems. Given infinite time to complete the task, either strategy will deliver the acceptable answer eventually -- provided, of course, the important factors do not change in the interim and Chinese baseball does not hold.

When only a limited time is available, however, the test showed that the wholist strategy is superior. Since the factors impinging on contemporary problems are continually changing, since time always seems severely limited, and since we cannot afford to be wrong on the major decisions affecting man, it would appear that the wholist strategy is the preferable one in general. This again stresses the instantaneous apprehension of the totality as a most desirable trait even for practical situations.

Subsuming and Resonating

To be realistic about the matter, however, very few of us are paid to teach the totality. We are assigned only specified bits and pieces. But in teaching these specified parts of the totality, we are expected to give meaning to them. How we can go about maximizing such meaning is, of course, of direct significance. I would, therefore, like to stress this aspect by subsuming and resonating.

Let us see how it would be applied in your own interest of unified science education.

In this connection, I would like to recall the first guideline on the preparation of a unified science unit, as described in the Autumn 1973 issue of Prism II. According to this guideline, the unified science unit is to be organized around one of four themes. These are: 1) a big idea or concept that permeates all science, 2) a process of science, 3) a natural phenomenon, and 4) a persistent problem of the science-in-society type or from within science itself.

If we examine these themes carefully, we will note that they may actually extend far beyond the boundaries of the natural sciences and even beyond those of the social sciences. Take the first theme: a concept or idea that permeates all science. It can well be that such a theme permeating all science might also permeate all human concern. As a matter of fact, a philosophically-minded person might even argue that a theme that *permeates* all sciences *can* only be formulated in a language that *transcends* the sciences themselves.

You have lent some credence to this interpretation in your own approach to unified science education. What you seem to have said in effect is that by means of some unified perspective of all the sciences, a specialist in one particular science would be better able to appreciate its significance within the sciences to a much higher degree. He would gain a broader-based perspective in what he is doing in his specialty.

In applying the art of subsuming and resonating, we will first have to select the level of our operational concern and the level of our contextual concern. If we must insure that our students receive their credits in chemistry when they apply for admission to college or graduate school, for example, we may regard the specialized sciences as our level of operational concern. The unified science then becomes our level of contextual concern, which is to provide the broader-based relevance, perspective, and meaning to chemistry.

Subsuming would suggest a step beyond the level of operational concern. In unified science education, therefore, this would suggest a dissolution of the boundaries between, say, chemistry and physics, as you are trying to do. Dissolving the boundaries alone, however, would lead us right back to the very pitfalls of conventional multidisciplinary approaches, of which we have just spoken. We would end up with an intellectual quilt, in which different patches of chemistry and physics are sewn together.

In the way we are using the word, subsuming means much more than mere dissolution of boundaries. It means an assimilation, an assimilation akin to the molecule of carbon dioxide being assimilated into carbohydrates in photosynthesis. There is an actual disappearance of its being in the higher synthesis.

Yet since we are operationally interested in chemistry, we cannot afford to lose track of it. We must, therefore, still retain the identity of the conceptual entities called chemical principles, which would flow from the context of the subsuming whole. We would resonate the identifiable conceptual parts called chemical principles against the unified conceptual whole called unified science and vice-versa. Out of this subsuming and resonating, we achieve the sense of belonging -- that is, meaningful relevance. The individual part is given a place in the scheme of things and the scheme of things allows for its individuality.

Now, if we wish to give greater meaning to unified science education as a whole, we would then adopt unified science education as the operational level of concern. We would subsume it within a transcending context which we may call for the moment, unified learning. Finally, we would resonate the conceptualized component of unified science education against the conceptualized whole of unified learning and vice-versa.

We can extend this progression into successively larger contexts. Eventually we arrive at the mark of the wise man, which is, as we have mentioned, the instantaneous apprehension of the totality. This is the orientation that we are proposing for a post-graduate course in unified science education.

Concluding Remarks

In closing, I would like to suggest that one of the greatest deficiencies underlying scientific attempts at the resolution of contemporary problems is the vector quality. We do not know what direction we are really heading other than more of the same. We lack the transcending contexts to give lasting meaning and value to much of our operational concerns.

For a particular science to be truly meaningful, it must be given a perspective and a vector within the context of unified science. For unified science to be truly meaningful, it must be given a perspective and a vector within the context of unified knowledge. For unified knowledge to be truly meaningful, it must be given a perspective and a vector within the totality of man. The parts must be subsumed within the whole, yet keep resonating with the whole and with each other.

In this way, unified science education will always be operating in the vectored instant -- always in the instant of action with the vector of social beneficence.

"Understanding Our World"

by Erwin M. Segal

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Since the middle of the Nineteenth Century and before, scientists and natural philosophers have been fighting a major war against mysticism, magic, and their allies. Although the war has been bloody at times, for the most part it has been a war of words and deeds to gain control of the mind of man. One problem that we face today as scientists is that the war has, for the most part, been won and the few enemy that remain have erected strong defenses against the major weapons in use. Not only are those weapons no longer functional, but may actually be self-defeating. Still, many scientists and supporters of science continue to use them. It is time to re-evaluate our weapons, to select from our stockpile those that still work, and to discard the rest.

General knowledge of the world in primitive and medieval society consisted of being aware of the many ghosts, goblins, and gods that inhabited and controlled all of nature. The basic mode of explanation of any event was that some independent source of action was the direct cause. For example, if someone became sick, he may have been punished for his sins by some consciousness which was imposing the infliction on him. If he acted strangely, he was possessed by some demon; if his crops failed, it was because some god or other was displeased and was punishing him. If an event occurred that was unexpected or slightly different from the ordinary such as a comet appearing, some god somewhere was angry and there would be hell to pay. If something good happened like a bumper or the birth of a healthy son, the person had done well and the gods were pleased. Natural events such as the birth or death of a baby, the running of water downhill, the growing of wheat, the coming of a storm, were all understood by the play and counterplay of natural, animate, and supernatural forces. The world was populated by souls, gods, and demons which, by the way, not only populated our world but other worlds that we may have had some feel for but no knowledge about.

Scientific models and methods developed in this world which was populated by magic and mysticism. It was against these enemies that science aimed its mightiest weapons. It is true, of course, that the enemies have not been vanquished; they are relatively weak, but witches, mysticism, and demons have not been exorcised from western man. Exorcists are still exorcising them one at a time with a large amount of support from from a surprisingly large part of society!

As you can see, the world that we lived in, until the Renaissance and beyond, was peopled and generally filled with many different kinds of natural and supernatural things. There were conscious powers and forces controlling us and making things happen. Science did live in the world prior to the Renaissance and some scientific explanation of events was proposed but, for the most part, it - that is science - did not attempt to lay claim to the general nature of things. There were Greek scientists such as Democritus and Archimedes who had articulated a natural theory of motion; Aristotle had a physics which explained, according to what may be viewed as natural reasons, why the earth was at the center of the universe, and both he and Ptolemy had some explanation of why certain "stars" wandered from their position among the others. Even some early scientists made enemies. For example, Anaxagoras was prosecuted for impiety because he believed the sun and moon were not alive,[2] and we all know the problems of later scientists such as Galileo and Bruno.

Specific Battles - General Principles

I don't have a scholarly or detailed knowledge of the history of ideas, but I would think that the battles between the naturalists and the supernaturalists were waged in the beginning only in the specific domain in which a disagreement occurred rather than over a general characterization for understanding the world. I also believe that the advantage, for the most part, went to the naturalist, partly through technological advancement. One problem with the world filled with unknown beings is that one could try to appease them, but one could not control them. The natural philosophers and technologists, to the extent that they were successful, could demonstrate that they knew what they were doing. It may be that the stronger god was on the side of the victor--but if one side had cannon and the other swords, God was invariably on the side of the cannon. Gods may have directed some men through the storms of the sea, but if the captain had a lodestone, he knew where he was going during the storm, etc.

Starting with modern philosophy, perhaps Descartes--or Copernicus--or William of Occam, there was a tendency to eliminate the supernatural as much as possible and claim more and more space for natural processes. William of Occam suggested that if anything could be explained with fewer entities, more should be avoided.[3] Exorcise the demons. That was early in the Fourteenth Century. Copernicus applied that principle of parsimony over the mathematics of the heavens, and in so doing attacked theological explanations.[4] Descartes, after studying mechanical contraptions such as fountains and music boxes, and viewing drawings of gross anatomy based on human dissection, suggested that all events of the physical world including bodily function could be explained by natural processes, most likely by the laws of mechanics. He kept as an exception only that part of the behavior of man that was controlled by his free will.[5] So with the start of modern philosophy, a suggestion of natural understanding of the vast majority of the world was made.

By the Nineteenth Century, the scientists were feeling their oats. In 1845, four soon to be famous physiologists, Brucke, Ludwig, DuBois-Reymond, and Helmholtz, actually mad a pact to fight vitalism--to eliminate mystical forces, even from mind and behavior--specifically to allow only physico-chemical forces to be used to explain events in physiological systems.[6] By the end of the Nineteenth Century, naturalism had the battle against supernatural forces all but won.

In the Nineteenth Century, however, certain individuals, with prior support from important scientists and philosophers like Newton and Hume, attempted to commit the final exorcism and to make sure mystical explanation disappeared altogether. They were the positivists. Comte, in the earlier part of the Nineteenth Century, and Mach and others later took the strongest definition of Occam's razor and claimed only those entities that are the most necessary, only those that are directly sensible are allowable into science.[7] For them, if you can't feel it, see it, taste it, smell it, or hear it, it is not there and cannot be used in understanding the world.

Twentieth Century Views

The position of the positivists and very similar positions have, in the Twentieth Century, become a major force in the philosophical description of what science is and what it ought to be. The demons of the Eighth Century have been exorcised by the positivists of the Twentieth Century. In what state does that leave understanding the world? Right now many, if not most, philosophers of science, physicists, and psychologists are positivists or have strong positivist learnings. They believe that fundamental concepts, as well as data, are determined by the observations that one makes in as objective and reliable way as possible. Scientific knowledge, or knowledge of the world, consists of statements which are at base inductive generalizations of these observations. All terms that they use as bases for understanding are either names of observable events or defined in terms of observable events. Their only goal as scientists is to get a simple description of their observations and potential observations.

Much of the theory of scientific explanation in the Twentieth Century has been developed either within a positivist framework or as minor extensions of the positivistic framework. The Twentieth Century positivists, particularly logical positivists, were quick to point out that any statement that could not be verified by perception or through the senses was non-sense, and they meant both meanings of the word.[8]

The logical positivists, again following Hume, argued that there are two kinds of statements that can enter scientific discourse. First, there are analytic statements, the statements of logic and mathematics. These statements make truth claims that can be determined by the meanings of the terms themselves and need no external verification or confirmation. They include only definitions and tautologies, statements such as "A bachelor is not married," "2 and 2 equal 4," and "It is either raining or not raining here now," were considered either definitional or derivable from definitions. One knows all logical facts for certain because, given the meanings of the terms, there is no empirical information which could falsify the information; they are true in any possible universe.[9]

The second kind of statement was the synthetic or empirical statement; these are statements which can be verified by observation. These include such statements as "Grass is green," "Acceleration of a freely falling body is constant," "It is currently raining," etc. Particular empirical statements can be confirmed by observation, but universal empirical statements, since they are only indictive generalizations from the particular, can never be known for certain. Thus knowledge of the world is always tentative knowledge. Certain knowledge is limited to tautologies and current observations.[10]

Although the positivists made claims that, as far as scientific knowledge is concerned, one never knows for sure, they were deathly afraid of coming to erroneous conclusions. If ever a theory was later disavowed, someone could show where that theory was not appropriately verified. It had some component or other that could not be reduced to observation. Thus, it was claimed that the theoretician had not followed scientific methodology entirely. It was believed that those components which were scientific remained true and only the nonsensical material would be rejected. It is for this reason positivists decided that: Aristotle's comments about natural places and about nature abhorring a vacuum; Newton's comments on absolute space and time; Priestly's defense of phlogiston; the belief in the ether; and so on, were non-scientific claims.

Since the principle of verification was the primary principle of logical positivism, and since only verified statements are admitted into the body scientific, the discussion of what can be verified and how it can be verified became a major source of inquiry by those seeking scientific knowledge of the world. The positivists tried to observe these principles.

Only those terms which can be verified have meaning; if they cannot be verified, they are nonsense. Verification, and therefore meaning, was dependent upon empirical support. The meaning of a term became its method of verification.

I have neither the time nor the inclination to go into detail on the troubles and modifications that went into the development of positivism. Suffice it to say that in the early positivism of Hume and Mach, terms were defined by the sensations which accompanied them. Since sensations are personal - I have mine and you have yours - it is difficult to use them as the basis of a public enterprise. The logical positivists later used ostensive definition as the ultimate experiential base for terms which had high "intersubjective testability," in other words, terms that different people could agree were descriptive of the phenomena. These would include such things as identifying a color as red, or a surface as smooth, but mostly, for maximal reliability, they preferred pointer readings on a mechanical instrument.

Another doctrine that has high support in philosophy, psychology, and physics is called operationalism. In this form of positivism, a term or concept is defined by the procedures by which it is measured. It is this position that leads to such insightful definitions as "Intelligence is what an I.Q. test measures," and "Electricity is the deflection of an ammeter." This sort of definition ran wild in psychology in the 1940's and 50's, and for all I know, may still be very popular in some circles. Skinner, for example, defined "hunger" as number of hours without food,[11] and Hull defined "habit" as number of reinforced trials.[12]

Scientists who claimed to work within one or another positivist framework included Mach, Heisenberg, Bohr and the Copenhagen school of physics which currently dominates the high energy field, and Skinner, Hull, and Tolman, the three major developers of behavioristic theory in psychology. Bohr developed, for example, the complementarity position which is accepted as absolute truths by many physicists.

Positivistic Explanation for Light Phenomena

Prior to 1900, most physicists believed that light was a wave similar to the wave that appears in a body of water when a pebble is thrown in it or to a wave that may occur in a rope when you hold the end and give it a flick of the wrist. As we all know, a wave requires a medium to travel in. No substance moves when a wave travels. Only energy moves due to repeated local effects in the medium. Michelson and Morley hypothesized that if the earth was moving through the ether, and by then everyone knew the earth moved, waves going in different directions and returning to the starting point must take different amounts of time to travel the same local distance. However, several experiments showed the light always took the same time and modification had to be made in the ether theory. Positivists concluded that since we could never see the ether, we should have never hypothesized its existence in the first place. The complementarity position claims that under certain circumstances light and other electromagnetic phenomena must be treated as a wave. The wave description explains interference phenomena, diffraction, and so forth. Under other circumstances, the description that is adequate to describe the phenomenon is that of a particle--as in the cases of the photoelectric effect, Brownian movement, whole number features of energy transmission, and so on. The wave or the particle in each instance is seen as descriptive--not explanatory--and we cannot find or even hypothesize any underlying reality and still be scientists. Since each of the modes of description has its own observational contexts and the two contexts differ, it is argued that both the wave and the particle descriptions are accurate. This makes sense from a positivistic viewpoint since each context defines the method of verification which is the definition of the term. What the character of light is in reality is of no consequence, and as far as science is concerned, a nonsensical question.

Shortcomings of Positivism

The positivistic approach just outlined may work as a reconstruction after the fact to describe observable events, but in no way does it account for the actual scientific process as practiced by real scientists.

Recently, certain individuals, rather than simply reconstructing the history of science from their own particular point of view, started looking in some detail at a few historical cases in the development of science. Several of these individuals have come to conclusions that have a great deal of similarity, although they differ enough to have battles in the literature.[13] Three of these individuals are Thomas Kuhn, Norwood Russell Hanson, and Paul K. Feyerabend. Kuhn's 1962 monograph for the International Encyclopedia of Unified Science, "The Structure of Scientific Revolutions," is the book that rekindled my interest in the philosophy of science and got me to rethink what the scientific enterprise is all about. Hanson wrote a 1958 monograph, Patterns of Discovery, describing the process in which scientists develop theories. Hanson also wrote several very enlightening articles on the picture theory of theory meaning which I think is an accurate account of scientific theory.[14] Feyerabend has many articles[15] on problems of formal scientific methods which I also have found very enlightening. I think that each of these scholars takes a position that is consistent with my view of natural science, although Kuhn may be less committed to a particular view of science.

The Nature of Science

I was taught in my science and philosophy courses as a student that the most important characteristic of science was its method. I believed that for a long time, and even now I cannot completely reject it. I think that methods are important--but as tools, not as the product. Science's major contribution is an attitude and a way to think about our world in all of its manifestations. Kant realized this but Hume did not. Science is not a limited method in which one has some hypothesis about an observable sequence of events and then observes whether that sequence occurs or not so the hypothesis could be verified or refuted as the hypothetico-deductive method implies. Nor is science an interrelated set of statements which has certain observable deductions which, in the appropriate situation, can be observed. What science is, primarily, is a way or mode of understanding nature. It is a way of understanding our world. The historical term which identifies those who accept scientific explanation is "naturalist" or "natural philosopher." Of course science should be studied in a unified manner. There is only one world in which we live and all aspects are generally studied from a single orientation or point of view. That is basically what Kuhn meant when he said that a scientist does his work from a particular paradigm. However, all scientific paradigms have certain characteristics that they share or ought to have characteristics that they share.

The scientific or naturalistic way of understanding the world is that events in the world proceed in an orderly fashion. They are not capricious, and they are not controlled by some unknown intelligence that can interfere with the order at will. A scientist believes that the events which he or she observes can be understood because they flow in an orderly fashion from some underlying reality. If he or she can intuit what that underlying reality is, what is observed can be understood. Since our observations are not very continuous and regular, we assume that we see only part of the reality. The cliche of the tip of the iceberg is appropriate here, either as an analogy, or as an example. We know that the natural processes of a liquid imply that if an object floats in it, the object displaces a volume of the liquid equivalent to its weight. Since ice is only slightly lighter than cold water, we assume that if it is floating in water, most of it is displacing water and we cannot see it.

Science is tough--it is not an automatic process that can flow in simple order from methodological prescription. I do not expect computers to do science for a long time. Science requires that one make use of all possible intuition and creativity. Man must invent the underlying regularity in nature since man cannot see it. The underlying reality is just as real as the observations that confirm it. I do not believe that any practicing scientist disagrees with this regardless of what he says on the matter in public.

Let's consider the simple example of a stick. We observe a straight stick. It is put halfway into some clear water. We see a bent stick. We take it out. We see a straight stick. Although Mach claimed otherwise, everyone believes that the stick was still straight when it was in the water. Why? We could believe that some poltergeist lurks in all clear water to bend sticks and confuse us. Instead, we choose to believe some wild story such as light, which usually travels in a straight line, chooses to bend when it comes to the water-air surface and, although we cannot see the light rays, we see the effects of the bending. The underlying reality of rigid bodies and local effects of light rays can be put into a coherent framework of rigid bodies and light rays in other situations so we understand nature better, by postulating regularities of performance under a variety of conditions, because the underlying reality is coherent.

As scientists, we build a scenario from which the observable and observed events flow naturally--even automatically. To the extent we succeed, we have evidence that the scenario that we build is an accurate one. If we fail, we attempt either to construct a new scenario or to modify this one to account for what is observed. Another aspect of this method is to extend the natural processes identified to figure out how to generalize them so that they account for observations which have heretofore not been conceptually connected to the original scenario. A theory that extends in a simple and natural fashion into new domains has high chances of remaining operable for a long time in the domain of science and to play a major role in understanding our world.

The scenarios, the proposals that we make about the underlying reality, are the fundamental bases of science. We also assume that this underlying reality acts in a regular and coherent way, so if it has certain characteristics, they will show up whenever the conditions are ripe. The purpose of studying methods in science is so that we will know how to find out what those regularities may be--in the most efficient way possible.

Scientists May Not Understand Science

Many scientists, and some very famous ones, do not understand the general nature of their discipline, although in most specific situations they may act as I have described. Einstein became aware of this before his Herbert Spencer lecture at Oxford in 1933. At that time he uttered the now famous statement:

> "If you want to find out anything from the theoretical physicists about the methods they use, I advise you to stick closely to one principle: Don't listen to the words, fix your attention on their deeds."[16]

It was at this time he pointed out that, although he had claimed to be a positivist for many years, he now realized that he was in fact a realist. Not a naive realist because he knew quite well that our observations are fallible. He was a realist who believed that our observations could be explained by an underlying reality. Since this reality could not be seen, it had to be constructed by human intelligence. To quote Einstein once more:

> "We are concerned with the eternal antithesis between the two inseparable components of our knowledge, the empirical and the rational ....The structure of the system is the work of reason; the empirical contents and their mutual relations must find their representation in the conclusions of the theory. In the possibility of such a representation lie the sole value and justification of the whole system, and especially the concepts and fundamental principles which underlie it. Apart from that, these latter are free inventions of the human intellect, which cannot be justified either by the nature of that intellect or in any other fashio a priori."

Even though Einstein thought that a rational theory must have empirical justification, having empirical justification was not enough to support a theory. I will quote one comment he made in which certain supposed facts fit other theories better than his own. "In my opinion, both their theories have a rather small probability, because their fundamental assumptions concerning the mass of moving electrons are not explainable in terms of theoretical systems which embrace a greater complex of phenomena."[17] Before you get the idea that perhaps this was a later senile Einstein talking, you should realize that the last quote was made by him in 1907 when he still envisioned himself as a strong positivist.

Galileo was supposed to be one of the first modern scientists. What kinds of procedures did he use? We know that he made a telescope and looked at the planets. He supposedly saw the four moons of Jupiter and the craters on the moon. We have also heard that the professors refused to look through his scope because they were fearful of what they would see. But Feyerabend reports a detailed case study of Galileo and it seems that many people did look through the telescope at the heavens. It also seems that those who looked disagreed about what they saw. Galileo did not have good telescopes and what was seen in many instances could be refuted by the naked eye. One sometimes saw double stars of the same magnitude where only one was seen with the naked eye. Colors were sometimes seen around the edges when the naked eye showed none, and so forth.

Moreover, Copernican theory, as advocated by Galileo, was obviously refuted by the naked eye. It would predict large differences in brightness for Venus and Mars up to a factor of 40. Yet the differences are quite small, 1 magnitude and 4 magnitudes respectively. The events on earth also clearly refuted Copernicus. Objects which fall can easily be seen to fall <u>in a straight line</u> towards the center of the earth. Cannon fired to the east and west went the same distance and those fired north or south traveled accurately rather than missed on the west.[18]

In fact, seeing the moons of Jupiter in no way confirms Copernican theory--so there are 11 moving heavenly bodies rather than seven. Also, Galilean dynamics, even if true, do not prove geocentric theory. Although seemingly refuted, Galileo thought that the Copernican system made sense and events seemed more natural. Moons could go around Jupiter on the earth, and all could go around the sun. There seemed to be conceptual harmony. In addition, although the telescopes were poor, the brightnesses of Venus and Mars seen through the telescope did seem to be in line with Copernican predictions. So a feeling for consistency in nature plus arguments which seemed to work against the obvious experience of the non-moving earth laid the foundation for modern science--not as some would suppose, inductions from observables.

Science in Everyone's Life

It is unlikely that we can all be Galileos but we all can learn from Galileo. The methods we use in science should support our ideas and concepts, not precede them. Our goal as scientists is to make sense out of our experiences; to use our knowledge of other events and experiences; to use our intelligence and intuition, to account for those experiences by filling in the interstices. If we are successful, the experiences can be seen to follow naturally from the general conception.

We should be aware that inventing the appropriate framework is sometimes very hard work and sometimes we invent faulty solutions. However, that does not mean that we should give up and claim the experiential description is the best we can do, nor that we need supernatural intervention to fill the interstices. It just means we are not finished.

Scientific inuitions can be developed and with it perhaps scientific attitudes. If someone is working on a problem and he can see the framework of an orderly solution, he more than likely will be able to accept natural explanation and to work out the details fully. In other words, he is more likely going to be a scientist. If he is only given a magic show, he is more likely to equate science with magic and become one of the 36% of Americans who believe in possession by demons.[19]

I have seen--presented as science--a mercury hammer drive a nail after the mercury was submerged into liquid oxygen; someone speaking in a squeaky high-pitched voice after inhaling helium; sparks flying into milk bottles after dropping a match into the bottle, and many more. I have also seen magicians turn liquid into solid, pass coins through solid barriers, and so on. The magician does not tell how he does it and, in many instances, neither did the scientist. There is a tendency to mystify. What we need, at least in part, are simple phenomena and an explanation of those phenomena. We could then progress to more complex phenomena and perhaps a way to generalize our earlier explanation of those phenomena. In addition, we need a natural framework to view certain complex phenomena, even when we do not currently have the mechanisms worked out.

In the behavioral sciences, particularly psychology, many, if not most, people do not see a natural framework for an explanation and have retreated to the possibility or even probability of mystical explanation.

Two mechanistic approaches, behaviorism and psychoanalysis, have claimed the minds of many of us as the framework for understanding behavior. However, mechanistic approaches have been shown to be limited in physics and the two psychological ones are both unable to handle certain behaviors and cannot specify the way they might occur. Because of this, even some biological scientists have been returning to the possibilities of mystical models to fill the interstices.

I cannot explain why people see flying saucers nor why they believe that demons possess people. I do believe that people's actions and beliefs can be explained by natural processes. We know from the analyses of control systems by Norbert Weiner[20] that all one needs is infinitesimal amounts of energy to control large energy systems and, also, that the pattern of events can be more important than the quantity of energy. These patterns can be studied conceptually and natural regularities can be found. We know, for example, that if you hear several sentences about a given topic (i.e., if you are on the receiving end of a discussion), you may remember the sentences as auditory strings but you will not understand them that way. Rather, you will construct an accurate representation of an integrated scenario and use that for your decisions. We know this because, under the appropriate conditions, people can answer questions about inferences from the dialogue faster and better than questions directly concerning the dialogue. We know something about how people remember and use the information they receive.[21] The underlying descriptions of this knowledge may be generalizable to regular cultural patterns of belief.

The major character of naturalistic understanding of our world is an attempt to construct or invent a coherent underlying reality from which observations flow naturally and automatically. It is not to articulate sentences which have logical connections among them and others which correspond to observables. The sentences used by scientists describe a reality--they are not themselves fundamental objects in a theory. If we think of the sentences and the observations as the only reality, we leave many conceptual interstices and no basis for understanding. Each observation becomes an isolated reality and terms have no meaning. With 1984 near and positivism rampant, we can claim that a wave is a particle and a twin is both older and younger than her sister. I may also claim, with more logical consistency, that the stars compel me in a particular fashion because of the time of my conception or that the devil made me do it.

Conclusion

In conclusion, I have argued that attempts at understanding our world has taken one of three different forms. First there was the animistic or supernatural form. Events occur because some intelligence wills it and makes it happen. The decision processes these individuals use cannot be deeply understood but we might get some results and could perhaps predict and explain what happens by either appeasing or threatening the doers of the actions. In this framework of understanding the world, the world is peopled by many mysterious and unknowable forces.

In opposition to the supernatural position, a positivistic theoretical position developed. This position claims to be theoretical since it concludes only that which is conclusive. There are in this position no supernatural entities causing the events in the world, but no natural entities either. The position is in reality totally unknowing of why anything occurs at all. To the extent that the positivistic framework is followed, all we can ever have is description of those events we observe and we could never really understand our world.

The third position, the one that allows for the greatest creativity and intuition in our quest for understanding our world, is the one that I have dubbed the naturalist position. In this theoretical position, we assume that a systematic and coherent set of natural phenomena underlies our specific experiences and we as scientists try to hypothesize and hypostate what those underlying principles and processes are. To the extent that they give a simple and accurate explanation of the phenomena we observe, we accept those hypotheses and hypotases as true explanations of our world. This latter position suggests that, rather than emphasize facts or even methods as the foundation of science, we should emphasize understanding. We should emphasize that there are entities and processes in the world that function in an orderly and predictable way from which observations derive. And finally, there is the possibility that, if we can invent the underlying reality, all events in our world can be understood.

Footnotes

1. A poll by Louis Harris found 25% of people polled believe in the ceremony of exorcism. Buffalo Evening News, April 1974.
2. Bertrand Russell, A History of Western Philosophy, 1945. Since I do not pretend to be a historian, most of my older historical facts come from secondary sources.
3. ibid. p. 472.
4. Thomas Kuhn, The Copernican Revolution, 1957.
5. Richard Herrnstein and Edwin Boring, A Source Book in the History of Psychology 1965, pp. 266-272.
6. Edwin Boring, A History of Experimental Psychology, 1950, p. 708.
7. ibid. pp. 394-395, 633.
8. Some of the characteristics of logical positivism are outlined in Herbert Feigl's "Some Major Issues and Developments in the Philosophy of Science of Logical Empericism" in Volume 1, Minnesota Studies in the Philosophy of Science, edited by Feigl and Michael Scriven, 1957.
9. ibid. pp. 6-11.
10. ibid. same discussion.
11. Behavior of Organisms, 1938.
12. Essentials of Behavior, 1951.
13. Imre Lakatos and Alan Musgrave, Criticism and the Growth of Knowledge, 1970, is an example of such controversy.
14. "A Picture Theory of Theory Meaning" in Robert Colodny, The Nature and Function of Scientific Theories, 1970.
15. For example, "Problems of Empiricism, Part II" in Colodny, op. cit.
16. Quoted in Gerald Holton, Thematic Origins of Scientific Thought, 1973, p. 233.
17. ibid. p. 235.
18. Feyerabend, in Colodny, op. cit.
19. Harris, op. cit.
20. Cybernetics, 1948.
21. Robert Lawson, Memory for Information Conveyed by Semantically Interrelated Sentences, State University of New York Dissertation, 1974.

"Unified Science Education - Today and Tomorrow"

by Victor M. Showalter

Dr. Victor Showalter is presently Director of the Center for Unified Science Education. He was born in Dayton, Ohio, in 1927 and received his B.S. and M.S. from Otterbein College and The University of Wyoming. His Ph.D. is in science education from The Ohio State University.

He was a founder of the Federation for Unified Science Education. His publications include Man and the Environment (coauthor, Houghton Mifflin, 1971). He has received the Gustav Ohaus Award (1972) and the STAR Award (1960).

The present status of unified science education is somewhat difficult to appraise. The reason for this difficulty is that I would like to avoid the use of numbers because numbers are so impersonal and can not provide an adequate picture. However, in the limited time available, it seems that numbers are necessary.

Today we know of about 170 unified science programs in the world. Of these, there are about 150 in the United States. Some of the programs are taught in groups of schools. Others are taught in single schools. Some involve whole nations. There are further differences that become apparent when one looks closely at the programs. In fact, a characteristic of unified science programs, taken as a group, is their diversity. And yet, we in FUSE have believed for a long time that in diversity there is strength which is intensified by a general unity of purpose and basic philosophy.

The status of unified science is such that the numbers have increased and so has the diversity. The initial meeting of the group that formed the original FUSE organization was convened here in Columbus in the summer of 1966 - eight years ago. The group was composed of representatives from eight schools. These eight plus one that was unable to send a representative were the sum total of unified science programs known to exist in 1966. (1) This was a relatively slow beginning considering that we initiated the first unified science program here at the University Laboratory School in 1969. And yet, if one looks at a time plot of the number of existing unified science programs as David Cox did last year, the curve looks very exponential (1 in 1959, 9 in 1966, 170 in 1974).

The first annual meeting of FUSE brought together eight people who were interested in developing programs that dissolved or at least minimized the differences and boundaries between the sciences for school instructional purposes. The name FUSE was suggested independently by Carl Pfeiffer of Monona Grove, Wisconsin, and by Leo Klopfer, then, of the University of Chicago Laboratory School.

It is apparent that the short history of unified science education can be interpreted to suggest that unified science is the "coming thing." However, as many of you have heard me say many times, this, in itself, is a bad reason for undertaking a unified science program. The history of American education is full of innovations undertaken for the wrong reasons which in the long run "killed" some pretty good ideas. Thus, I believe that we in FUSE must be very careful not to catalyze any bandwagon effect relative to unified science. This doesn't mean that we should completely avoid some proselytizing. It does mean that we should not picture unified science as a cure-all which it is not anyway.

Much more important than the fact that we can show growth in the numbers of unified science programs is the fact that the concept of unified science education has continued to grow and evolve. When the same people that met in 1966 talk about unified science today, it is very apparent that the idea has gone beyond its level of development then. I believe that the idea is still evolving and that is one of the excitements of being involved in unified science today.

Just what directions this continuing evolution will take in the future is hard to predict. It seems that every new program that is initiated takes a step in that direction if for no other reason than that which the unique characteristics of the school situation itself impose on applying a unified science approach.

Up until 1972, the FUSE group alone was responsible for disseminating the concept of unified science on a more or less informal basis since we all had other fulltime jobs. There was some mutual help in developing instructional materials through a sharing of materials, outlines, etc., that we each had developed.

In 1972, the National Science Foundation (NSF) provided a grant to FUSE to establish the Center for Unified Science Education. This was a landmark grant because it marked the first time I know of that NSF has provided such a grant to a professional association of teachers that was not primarily associated with one of the well established academic science disciplines. The grant is also significant because it marks a change in emphasis by NSF from focusing on science subjects as such to focusing on a goal of achieving scientific literacy by learners.

The creation of the Center has had an impact on science education in both the United States and the world. I believe that an examination of Center correspondence files documents this assertion adequately. The creation of the Center has also had an impact on FUSE itself, even though it is a functional branch of FUSE. A major part of this impact has been on the annual FUSE Conference.

In the past few years, a major function of the annual FUSE Conference has been to disseminate the concept of unified science education. Since the last FUSE Conference (October, 1972), the Center has conducted ten regional, intensive two-day workshops in various parts of the nation as part of its funded program. These workshops have had a total of about 800 participants. An additional estimated 500 people have had active contact with Center activities in one way or another. The current number of people receiving the Center journal (Prism II) worldwide is nearly 3000.

The annual FUSE Conference now can concentrate on the frontier and speculative aspects of unified science education while the workshops deal mainly with the transmission of ideas and techniques that are already fairly well developed. This does not mean that the workshops have been devoid of creative activity. However, it has constituted a rather small proportion of the overall workshop activity.

It should be noted that every regional workshop has been staffed by people from the Center plus FUSE activists from the general geographic region of the workshop. Thus, the workshops conducted by the Center have retained many of the cooperative aspects that typified early FUSE efforts and which were (and are) probably the key to their success.

Even though the activities of the Center have formalized some of FUSE members' previously informal activities, this does not mean the latter have been pre-empted or are no longer needed. In fact, there are many specific things that need to be done if unified science is to fulfill its potential. I would like to mention five such things in particular.

Passive Evangelism

First of all, it is necessary that all of us become or continue to be passively evangelistic. Now I don't mean that we should be out shaking tambourines. But, we should let it be known in our own part of the world that we are interested in unified science education, that we have done some serious thinking about it, that we either have an ongoing program or are considering one, and that we are available to share our ideas and to become involved with other people with similar interests. One way to do this is to write articles, contribute papers, make talks, etc., whenever possible. Potential audiences range from local, state, and national science teacher organizations, to service clubs, local citizens, and colleagues in the same school or school system.

Articles and talks could include case histories of unified science programs, blue-sky specultations on future directions of unified science, results of research and evaluative studies, descriptions of unique unified science units, etc.

Continued Progress

If we need a slogan to insure continued progress in unified science education, we might take our cue from a bumper sticker that I often see. It says, "Keep On Truckin'." Ours should read, "Keep On Learnin'." If any of us ever feel we have achieved the ultimate in unified science curriculum development, we are done. We will have lost the vitality that has been so characteristic of FUSE.

There is a type of natural reluctance to continue to explore new ideas that seems to afflict both teachers and farmers. I have often referred to this reluctance as the "Old Farmer Syndrome." It is based on a more or less true incident that occurred in Carrollton, Ohio, a few years ago. In Carrollton, the county courthouse is situated on a park-like square. Many of the area farmers congregate there and sit around and talk.

The county agricultural agent has found that this is a good place for him to contact the farmers and try to interest them in attending meetings, requesting literature, etc., designed to help them farm better.

One day as I was talking to the county agent on the square, he pointed out one old farmer who had never attended a meeting, never requested any literature, and, in fact never showed any interest in learning how to farm better. So I went over and asked the old farmer why he was not interested in learning anything new. He responded by saying, "Why should I go to the trouble of learning anything new when I'm not farming half as good as I know how to already?"

And so it is with many teachers. If I'm not using all the techniques and materials I already know about, why learn about more? Just doing a good job of what I'm doing now requires all the available time.

Now I am certain that all of us here realize that the times change and what we "knew" yesterday may not be appropriate for today. I am certain of that because, after all, here we are at the FUSE Conference.

Evolution of Unified Science Programs

Since most unified science programs are locally developed, they have a unique capability to evolve in time. They are able to respond to changes in student needs, community concerns, school emphases, etc. In many ways, locally developed unified science programs are much better equipped to play "Chinese Baseball" as described by Ralph Siu. (2) You may recall that in this game everything is normal except that after the pitcher pitches the ball and before it reaches the batter, the fielders can rearrange the bases. The name of the game may be the same afterwards but some of the "rules" have changed. And so it is with science education in a rapidly changing world. It is possible to make adjustments at least "between pitches" when the framework is that of a locally developed unified science program.

And so if progress is to continue, those of us who have ongoing unified science programs must not overlook this unique capability to adapt that we have. We must continue to make a conscious effort to facilitate evolutionary change.

A necessary condition to continuing evolution of a unified science program is the presence of a working philosophy, theory, or guidelines which establish the goals of the program and state the premises on which content selection and instructional methodology are based.

The ZAP Factor

The ZAP factor is and always has been a prime ingredient of every successful science program, whether it be unified science or not. This factor symbolizes the ineffable character of warmth and appeal to each participant's sense of fulfillment that makes the difference between an ordinary and a memorable science program (or science course).

I'd like to illustrate what I mean by a true story. A few years ago, I had occasion to teach a 12-week unit on outdoor science to a combined group of seventh and eighth graders. One of these weeks was spent at

Camp Kern near Fort Ancient, Ohio. During this week, each participant was involved in four half-day classes dealing with paleontology, botany, geophysics, and zoology. Each participant then conducted an individual study in one of these general topics during the last three days of the week. The area was unusually good for paleontology because of the great abundance of fossils (Ordovician) in the many ravines. Rather frequently, a student would find a trilobite and when this happened, there was a lot of exhultation. Everyone would rush to see it and the finder was a hero at least for the rest of that day. The finding of a trilobite - or even just the possibility of finding one was one of the ZAP factors for this particular program.

One evening, one of the students came to me with an extremely serious and concerned question. This particular young man had made a decision to do his individual study in geophysics prior to our going to the camp. His question was, "What is the geophysics equivalent of finding a trilobite?"

I think my answer satisfied him that there really was an equivalent. More importantly, for him, a ZAP factor was made apparent. I had not accomplished this previously for the general topic of geophysics, but ever since this incident, I have tried to identify the trilobite equivalent for whatever I was charged with teaching. And this is what we need to be certain we do in unified science because it is sometimes easy to lose sight of in the press of doing other things.

<u>Avoiding Commercialism</u>

The eclectic nature of most unified science programs is one of their greatest strengths. If a set of instructional materials for a one-year unified science program were commercialized and sold as an instructional package, this aspect would be lost. On the other hand, if a set of instructional materials is made available in parts without commercial strings attached, the spirit of eclecticism is not only retained but is fostered. We in FUSE have justified our faith in curricular diversity on the premise that the only instructional program that is taught in the spirit it was conceived is that which the teacher has had a hand in developing. Therefore, we must be careful not to do too much for teachers in other places in our sincere effort to be of help. Just where the line should be drawn is difficult to determine because it may be different for different school situations.

It seems to me that the dividing line beyond which extra help becomes self-defeating is between the module and unit levels. The latter are used in specific ways at the Center: a "unit" is a more or less self-contained segment of a unified science program which lasts about six weeks at the high school level and a "module" is one of several components that constitutes the unit and may last from two to ten days. This means that modules may be derived from an external source but that the synthesis of each unit should be done by the team of teachers that will use them. Those of you who have attended Center workshops will "see" this dividing line more clearly because of your experience with what we call the "modular unit."

Energy Imperialism

There is a real and continuing need to exploit sources of energy that are potentially useful in unified science curriculum development. We must especially seek out and exploit those human resources in the local scientific and higher education communities. The Center is a resource for unified science curriculum development for all groups, no matter how distant. However, if that distance is much greater than one or two hundred miles, the amount and kind of assistance that is available becomes limited. All resources should be used, but local resources are the most useful even though their very nearness seems to cause them to be overlooked all too easily.

This does not mean that a local university scientist should be enlisted automatically in a local unified science development program. There must be some selectivity because it is becoming increasingly apparent that some (many?) scientists are not very scientifically literate. It seems that a person can be a very good and successful scientist without really understanding the nature of science as a holistic and humanistic endeavor. He or she can know everything (?) about a given "field" and yet be unable to see the characteristics that link it to other fields.

Two examples of this situation were encountered in the preparation of this conference's program. One scientist frankly admitted that he commonly draws "solar system" sketches representing atoms as reflecting literal truth as opposed to a convenient scheme to explain certain phenomena. His concept of model is poorly developed, but this shortcoming does not apparently interfere with his daily work.

Another scientist, when asked to speak on the topic of "population" and how the concept is used and applied in his own field, responded that the concept was not used in his field. However, after a minute or two of explanation rescinded, he said that he had never really thought about things that way and yes, he would like to speak on the topic.

Another indicator of this situation was reported by Jungwirth in the February, 1974, issue of the Journal of College Science Teaching. He reported that some items on the Test On Understanding Science (TOUS) were answered incorrectly by significant proportions of 21 professors (in identified major fields) at the Hebrew University.

I believe that all of these examples reflect a growing demand that teachers of unified science at all grade levels must take an increasing responsibility for determining exactly what it is from science that should be taught to all learners. This increased responsibility also gives an unusual opportunity to review all of science and make some rational decisions on what constitutes scientific literacy and how these decisions can be implemented in the curriculum.

It should be evident that this responsibility is one that is continuous. It reflects at one time not only the premise for unified science education but also what is necessary if unified science education is to fulfill its prospects of profound influence on science education in general.

Unifying Concepts of Science

The premise that there are a number of powerful concepts that permeate all the specialized sciences has been assumed by many contemporary groups working to develop unified science programs at various educational levels. Most individuals in these groups have science backgrounds that are limited to one or two of the specialized sciences.

It was intended that the series of panel discussions conducted in this part of the FUSE Conference would enable five of these pervasive concepts to be examined from the position of several diverse specialized sciences and thus extend the perspectives of those interested in unified science curriculum design and development.

In addition, it was hoped that each panel's discussions would identify related and/or subsumed concepts and illustrate applications of the main concept in several of the specialized sciences. These, then, could be used by unified science curriculum groups directly in furthering their work. The five concepts for discussion were selected from the list published by the Center for Unified Science Education and included: "system," "equilibrium," "model," "cycle," and "population." Each panel treated one of the five concepts concurrently.

The summaries of the presentations and accompanying discussions have been prepared directly from the tape recordings by the editors. The tapes of the full sessions are available on loan from the Center for Unified Science Education. Each is about eighty minutes long. Except for some contributions made to the discussions by participants other than the panelists, the audio quality of the tapes is satisfactory for group listening.

Systems

Panelists: *Dr. Daniel Howland, Professor, Management Science, Ohio State University*
Dr. Stuart Thorson, Assistant Professor, Political Science, Ohio State University
Dr. Donald Wood, Professor, Industrial Design, Ohio State University
Chairman: *Dr. John Rheinfrank, Assistant Professor, Industrial Design, Ohio State University*

RHEINFRANK - Our purpose here today is to discuss the concept of "system" and some of the critical features of this concept that occur in our particular work. In some ways, the concept of "system" represents what science ought to be instead of what science has been. In this respect the concept of "system" gives people in different disciplines a common working paradigm or methodology to the end that they can work more effectively toward solution of very practical problems. The range of disciplines that are able to use "system" seems limitless at this time.

A very simple definition of "system" that we can use in our discussions is, "A complex of interdependent elements interacting within an environment." It should be noted that the "environment" referred to here could be on any scale from the submicroscopic to the macroscopic to the universe. The use of "system" leads to a view of the world that goes beyond the atomistic. The latter describes much of the history of science in which tradition dictated that situations be dissected into their simplest components before study. The systems approach is a reaction to this approach and aims to provide a coherent picture as opposed to a collection of fragmentary pictures.

HOWLAND - There are certain kinds of problems that must be viewed across disciplines. These problems typically are those that involve a multiplicity of probable causes. An example of such a problem is the automobile accident that results in a person's death. The death could be viewed as being caused by faulty brakes or heart failure. Technically, neither view would be wrong but also neither would be right if our ambition would be to prevent similar deaths. The systems approach and the concept of "system" are especially appropriate for handling this kind of situation.

Even though this example is oversimplified, it can also serve as a framework from which to make an important point about the systems approach. The point is that there are three different and more or less mutually exclusive operating principles on which to base a systems approach. These are: 1 - instrumentalism, 2 - optimization, and 3 - homeostasis. In the first, one believes that if every stage in a process is done right, the total effect will be all right. The second principle involves specific delineation of the goals to be attained and then working toward the most efficient way of attaining them. The third assumes that in a normal condition there is more or less a steady state and that interacting factors either work toward that end or actually adjust to produce that end in the long run.

No matter which operating principle is invoked, the whole business requires objective data and therefore adds reasonable and desirable rigor to thinking about a problem. This tendency to shift from biased opinion to an objective data base is representative of the whole business of science and therefore promises real progress.

THORSON - There seem to be two types of "system" ideas in operation. One is the metaphorical idea that typifies early applications of the idea to political situations. The other has more precision and is often labeled "mathematical." Both types are useful when applied properly.

There are three questions to be answered or decisions to be made in using the systems approach. The first is to identify the system that is to be considered. To a large extent this involves setting arbitrary boundaries of the system as it exists either in reality or in one's mind and there may be no difference between real and envisioned. The second question involves analyzing the system in terms of input and output relationships. The third question involves the type of representation to use in describing the system. This last question will be determined by many factors including the kind of data available, the desired function of end product, the personal preferences of the investigator, etc.

Ordinarily the desired function of the end product is to understand and eventually control varying inputs in terms of desired outputs. In political science there seem to be both goal seeking systems and adaptive systems that can provide the necessary thought structure for these ends.

In real life, each of us tends to "like" systems with relatively few variables and which are responsive. In a responsive system, if we do something, we see the results within a relatively short time and in reasonably tangible terms. However, many important systems are neither simple or responsive. They are complex with many variables and any effects of our manipulating one or more of these variables are either slow in happening or intangible, or too microscopic to be detected, or some combination of these. A formalized systems approach can thus enable us to handle many variables and to look at long range consequences.

A further use of a systems approach is that it enables us to ask questions that we otherwise could not ask or could ask only in very general terms which in turn could not be investigated scientifically.

WOOD - Painting is an alternative form of representing a system. The artist is aware of the dynamic interactions of elements such as shape, color, form, texture, etc., in a field. This is a possible answer to Thorson's third question.

AUDIENCE - Is there a conceptual threshold or prerequisite knowledge before "system" can be taught in the schools? Probably not, provided one was careful to restrict the learning to concrete situations for young children and to match the level of sophistication of older learners. In fact, there is probably good reason to begin a study of "system" at an early age considering its universal and unifying value.

Equilibrium

Panelists: *Dr. Dean Owen, Associate Professor, Ohio State University, psychology*
Dr. Dagobert Brito, Associate Professor, Ohio State University, economics
Dr. Larry Anderson, Associate Professor, Ohio State University, chemistry
Chairman: *Dr. Robert Steiner, Assistant Professor, Ohio State University, science education*

BRITO - Economics is a "relatively young science" [illegible]h "most of the theoretical work done in the past fifty years has [illegible]y people whose basic training was in the physical sciences." Thus, it is not surprising that many concepts such as equilibrium have been borrowed from the physical sciences.

The "old supply-and-demand" concept is like a kind of equilibrium condition in which the price of a certain object is associated with an exact match of the amount supplied and that demanded. Often, conditions like this are more or less "stable," depending on how sensitive they are to changes in external conditions.

Sometimes a market situation seems never to reach an actual equilibrium. The price of pigs may go up in response to an increased demand (or shortage of pigs) which is followed by an oversupply and subsequent falling prices. The cycle may then repeat.

The concept of equilibrium may be used to explain why, in a very mobile society, the "normal" unemployment rate is 4.5% but lower in a less mobile society. This percentage represents the number of people in transition from one job to another at any given time. The concept may also lead to a rather sophisticated expression as in Richardson's equations.

ANDERSON - Chemistry uses "equilibrium" in a "rigorously" defined way that is probably unique among the sciences but, when applied non-rigorously, has some observable similarities to its use in other sciences. A "stable" condition is a kind of equilibrium in which some specified "macroscopic property does not change." A condition of "balance" implies that there are two simultaneous and opposing processes in which there is no net change. The "mobility" of a system refers to its "intrinsic capability" to change from one equilibrium state to another.

Any use of the equilibrium concept, regardless of field of application, requires that a relatively large number of entities be involved whether they be pigs, as in economics, or molecules, as in chemistry.

OWEN - The function of "equilibrium" in psychology is that of an "explanatory mechanism." As such, it is one of many that have been borrowed from chemistry, physics, and physiology and are used "by analogy" in psychology. The probable first use of the concept in psychology was by the Gestalt psychologists in which the normal "mental state" was viewed as not simply at rest but being subjected to many "forces" to which adjustments were made to maintain the equilibrium condition. On a more sophisticated level, this has led to "adaptation level theory." Adaptation to distortion of visual figures and color based optical illusions can be explained with this theory.

Personality theory, Freud's theories, Festinger's cognitive dissonance (i.e., disequilibrium) are further examples of application of the concept. In general, "equilibrium can be an explanatory mechanism for a very wide range of problems in psychology ...but there are also cases in which it seems it should work but it does not."

DISCUSSION - Of the several questions raised, one seemed to have special significance, "Since it seems that natural systems tend to react to establish an equilibrium, does this hold true in economics?" Dr. Brito's response was that there are two schools of thought in economics; one would say "yes"; the other would say, "no"; and a great deal of heated discussion would follow.

Model

Panelists: *Dr. William Dancey, Assistant Professor, Ohio State University, archaeology*
Dr. Frank Verhoek, Professor, Ohio State University, chemistry
Dr. Ralph Hennen, Computer Center, Ohio State University, ecology
Chairman: *Paul Holobinko, Center for Unified Science Education, Ohio State University*

DANCEY - Models are statements of relationships between categories of data. Archaeology is relatively unsophisticated in the development and use of models. For example, one of the first models used in archaeology (in the Nineteenth Century) related man's predominant use of stone, bronze, and iron to time periods, hence the Stone Age, Bronze Age, and Iron Age. This is an ikonic model and one of a low degree of sophistication.

Presently, mathematical model and computer-generated model use in archaeology is increasing. A major problem in archaeology is "how to relate and model much of the mass of data now on hand." One answer to this problem is to apply models developed in other disciplines to appropriate archaeological data. An example is the application of an ecological model in relating climatic environmental change and prehistoric sequence in the U. S. Southwest to changes in human population size and distribution with respect to area resources. The model attempts to explain (in a simplified sense) the carrying capacity of an area in terms of the human population. Essentially, the model postulates that any environmental "zone" has a resource potential which controls the population size of that zone. When the carrying capacity is reached, the population size stabilizes by emigration, for example. Data related in this model come from dendrology, number of rooms in dwellings, etc.

The above example exemplifies the following features of model as used in archaeology.

1. Models structure research; they specify categories of data to be related and the relationship between them.
2. Models give direction to research and delineate the scope of research.
3. Models are "borrowed" from other disciplines and applied to situations other than those for which they were developed.
4. The appropriate application of models in archaeology requires "knowing the discipline (of archaeology)."
5. The models used in archaeology contain terms or expressions which are very often imprecisely expressed or defined.

VERHEOK - Science "produces" observations then uses models to produce a unified picture of the observations, that is, they are related by the use of models. Models are used to explain that which is unfamiliar and not understood in terms of that which is familiar and better understood. An example of the unfamiliar viewed historically would be "gases" which are "simply" explained in terms of familiar billiard ball interaction.

A more sophisticated and comprehensive model of gases is expressed as $PV = RT$ where T = temperature, P = pressure, V = volume, and R = a constant. This Kinetic Molecular Theory or model (some people use the terms "theory" and "model" synonomously) superceeded earlier models developed by Charles, Boyle, Hooke, and others. Over a period of time, models evolved from postulating that gases consisted of springs which expanded and contracted with temperature change to postulating that gases consisted of particles in constant motion, increasing or decreasing in velocity with respective changes in temperature.

Problems arise in teaching when familiar analogs are used to explain unfamiliar phenomena, but in actuality the analogs are also unfamiliar to many students. More time and effort are devoted to explaining the analog than the phenomenon itself. This requires students to learn two things instead of just one.

HENNEN - The dictionary definition of model is "representation." The definition of a mathematical model is "the set of intersections of a number of sets."

Models may be static (descriptive) or dynamic. An example of the former is an organizational model of government. Dynamic models explain "how things work." They may be continuous, e.g., explaining movement of water in a river. Or they may be discrete, explaining phenomena in a "snap-shot" sequence as a single instance of a predator capturing its prey.

Ecologists apply models in determining "what is going on in our environment." In environmental studies, environmental systems are modeled to determine the consequences of man's actions on the environment and to assist him in making decisions in regard to his actions. For example, a "river-flow" model whose components include the flow itself and the cycling of water between the river and surrounding area via evaporation and condensation, plants, animals, etc., is useful in predicting the consequences of such actions as damming a river. The power of this model is that it is cheaper than working directly with the river itself.

Another example of an ecological model is a "forest-model." The components include the horizontal "layers," such as, canopy, sub-canopy, smaller trees and shrubs, ground cover, as well as mortality, etc. The model helps explain population dynamics from layer to layer in relation to man's action on the forest. The model does not need to include all characteristics of the forest, e.g., diversity of species of trees, etc.

DISCUSSION - It was pointed out that the river and forest models as presented are simplifications, that is, the features of the phenomena are separated. The usefulness of the models results from taking each feature and specifying its functions as if it functioned independently of the other features. Thus, there is no attempt to interpret observations in terms of some inherent structure or process. Therefore, is anything new learned by separating the features of a river?

In response, it was stated that the river model's purpose was not to generate new knowledge but to predict the impact of man's actions on rivers. The forest model does predict new relationships.

Models were said to have different levels of complexity, i.e., they explain more observations until a model is identical to the real world. There was agreement that simplicity has to be one feature of models. The model must be simpler than the phenomenon being explained, otherwise there would be no point in making models.

The question was raised: "Since our observations related to the atom are 'secondhand,' can we say that the model of the atom is simpler than that which is being modeled?" The response was: "Yes, if you postulate that the atom is made up of electrons, protons, etc., then the behavior will be as predicted. You then no longer need to describe the behavior; you describe what is in the atom and how the parts interact. This is where the simplification occurs."

"The problem of having no way of really knowing whether the model is simpler than the atom is a matter for philosophy. Instead of asking, 'What processes would be observed if the atom were made up in "this" way?,' the scientist asks, 'What is the atom like?'. That is, most of the time he presumes there is a 'real' atom, and in this respect most scientists are realists."

Another question was asked about how "new" models relate to "older" models designed to explain the same phenomenon. One response was that older models are not discarded but are used in some instances. For example, in dealing with gases at fairly high temperatures and fairly low pressures, the simple "billiard-ball" model is an acceptable explanation. But if pressure is increased or temperature lowered, then the effects are explained only by the newer kinetic molecular model. The point is that simpler models are still used where appropriate, knowing they are not entirely correct. Another response was that in the case of the solar system, the older geocentric model has been discarded in favor of the newer heliocentric model. In general, models evolve and become more generalizable, are rejected, or are retained and used in certain instances even though incorrect.

In response to a question asking what advantages accrue when models are expressed in mathematical language, a number of advantages were identified. One is that these models reduce the ambiguity associated with the use of ordinary language. Another is that such models are very useful in generating new information. They suggest predictions or tests of the models to determine whether they are "correct." One must be careful with the use of mathematical models. Not all such models are based on "reality" but utilize logically developed constructs. The testing of "mathematical" models in science must be related to the "real" world.

In a discussion of the "correctness" of a model, such a model was judged as agreeing with related experiments or observations and having some kind of (correspondence) between the phenomenon being modeled and related observations.

Cycles

Panelists: *Mrs. Ruth Melvin, Assistant Director, Ohio Academy of Science, Columbus, Ohio*
Dr. Charles King, Executive Director, Ohio Biological Survey, Columbus, Ohio
Chairman: *Dr. Barbara Thomson, Coordinator, Center for Unified Science Education, Ohio State University*

MELVIN - Cycles are everywhere. Geologists also seek and utilize the concept of cycles. One of the most useful cycles in geology is the rock cycle. Both practicing geologists and lay persons are interested in learning more about this particular cycle although they are working at different levels of sophistication. Students find cycles interesting in their formal education if they have an opportunity to learn about them and apply them using concrete situations. The training of beginning geologists as well as the advanced education for potential scientists includes work with the rock cycle.

Geologists study the processes that transform and recycle rock materials of the earth's crust. These processes provide an understanding of the rock cycle as well as a way to classify and learn more about the rocks around us. Consequently, geologists are constantly gathering data and interpreting it in an attempt to advance geological understandings. The rock cycle also assists geologists in learning more about the various interrelationships which exist. The geologists who specialize in radiometric dating and the geologic time scale are also applying aspects of the rock cycle.

Some geologists work to help the public understand more about geology. One area which needs more exploration is the recycling of minerals. Geologists are aware that mineral resources are reusable and could be reclaimed. Public understanding of the rock cycle and mineral recycling could provide the necessary impetus to conserve these valuable resources. Eventually these discarded minerals again become part of the rock cycle but are lost as far as human uses are concerned.

The rock cycle is useful for synthesis purposes as well as categorization. The rock cycle is one of the most important cycles and should be readily utilized not only by professional geologists but by all people in society. It is a fascinating and educationally important cycle.

DISCUSSION AND LAB - A "hands on" laboratory experience was provided for all participants. A variety of rocks were distributed and categorized using the "rock cycle diagram." A discussion concerning rocks and the rock cycle flowed during this laboratory exercise. The majority of the discussion focused on classroom use of the rock cycle laboratory and the importance of this particular cycle for the education of all persons.

KING - Cycles, in the biological sciences, are numerous and are utilized extensively by researchers to extend their scientific knowledge of organisms and systems. Educators also use cyclic phenomena as a vehicle to extend their students' understanding of organisms. Since almost every organism on earth is subjected to regular cyclic changes of environmental conditions, this is one way cycles can be used to study organisms.

An ecosystem, however, is another challenge since it is a cycling system and within it are multiple functioning cycles. In viewing an ecological system, it is readily apparent that it is complicated. In fact, it is probably more complicated than we think it is. One person said that it is even more complicated than we think, we think it is. Consequently, the more we learn, the more we learn we don't know.

Both the biological research scientist and the science educators approach the complexity problem by identifying and working with the identification and study of individual cycles.

A microcosm is a useful model to use for the identification and observations of cycles. The more one can understand about a system in miniature, the easier it is to see the patterns and implications for macrocosms. A microcosm is a picture of the earth's mechanism.

One can start with the identification and study of simple cycles and move toward highly complex cycles which require mathematical models, e.g., nitrogen cycle, food chain, respiration cycle, photosynthetic cycle, Krebs cycle, etc. It is possible to identify cyclic and noncyclic systems and pose testable hypotheses, e.g., Is energy cyclic in this system? Is it also possible to explore contrasts among the cycles by manipulating biological variables such as top heavy, overloading, and carrying capacity? This type of exploration has implications for biology, history, and sociology.

It is readily apparent that cycles is an important concept in the biological sciences for both the practicing scientist as well as educators.

DISCUSSION - Dr. King brought a microcosm, which had been sealed and functioning since 1971, to the session. Questions were generated and cycles identified as were non-cyclic phenomena. Chemical materials, energy harvesting, and energetics were explored using microcosm observations.

Population

Panelists: *Dr. William Collins, Associate Professor, Entomology, Ohio State University*
Dr. DeWitt Davis, Assistant Professor, Geography, Ohio State University
Dr. Arne Slettebak, Professor and Chairman, Astronomy, Ohio State University

Chairman: *David Cox, Center for Unified Science Education, Ohio State University*

COLLINS - A population is defined, in the broadest sense, as a collection or aggregate of individuals or units that seem to have the same or similar functions. Populations may be continuous or discontinuous, spaced out or not spaced out, and randomly or non-randomly distributed in an area.

Populations possess a number of characteristics. One needs to keep in mind, however, that whenever dealing with populations you are concerned with averages since variation is one of the most basic characteristics of a population. This variation is absolutely essential in order for populations of living things to be successful. That is, if they had discrete values, there would be no way that populations could respond to changes in environment (e.g., changes represented by the addition of pesticides to or a decrease in oxygen in the environment).

Population density of living things is determined by a number of environmental factors - energy available, food chain, environmental factors (e.g., space, climate, relative abundance of water, various other kinds of plants and animals that are in the area), and biological factors (e.g., predators, parasites). There is increasing evidence indicating that some populations independently limit themselves to a certain population density (self-limiting).

The population concept is widely used in agricultural science since it enters into almost all basic research which is concerned with such diverse phenomena as pest control and plant breeding for maximum yield.

A new concept in pest control, "integrated pest management," has been evolving over the past five years. At its core lies a study of the pest population and subsequent determination of the environmental factors that provide resistance to population explosion. These factors usually incorporate such considerations as nutritional requirements, diseases, predators, parasites, and temperature extremes. The new trend is not to think so much in terms of controlling populations but more in terms of managing them. The goal seems to be to keep the population below the level where unacceptable damage is done.

DAVIS - There is a division of geography known as population geography. It treats the spatial variation in demographic and non-demographic qualities of human populations and is very sensitive to the time element. However, the use of the population idea is not restricted to this division of geography. The urban geographer views populations as aggregates of individual people and must use populations in studying his problems. The geographer is concerned with many aspects of populations, including distribution, composition, migration, and growth. The spatial variation of these aspects is extremely important.

Many factors influence these aspects. The population distribution over the earth's surface is very uneven. This is apparently caused by such factors as climate, physical relief, soil fertility, accessibility to sea and other transportation routes, availability of raw materials, and levels of development of cultures.

Geographers study populations at three levels - macro (e.g., world-wide), mezzo (e.g., national), and micro (e.g., city). Among the human population characteristics of interest to the geographer are differences and variation in sex, age, race, ethnic makeup, religion, education, occupation, and income. Mathematical and statistical techniques are used for making predictions, and an effort is made to keep as close to physical science methodology and techniques as possible when studying populations.

Model building is used to better understand populations and population attributes within a spatial context. One example of such a model is the Burgess concentric zone model.

SLETTEBAK - Spectral classification is one technique by which stars have been arranged into groups or populations on the basis of the appearance of their spectra. This type of population study has led to our modern idea of how stars evolve.

The background (continuous) spectrum of a star apparently has its origin in the hot interior region while the dark lines (absorption) spectrum) being impressed on that spectrum are the result of absorption in the cooler outer atmosphere. Since each element has its own unique spectrum, this provides a means of detecting the elements that are present in the star's outer atmosphere.

Hypothesizing about why different stars had different spectra has, historically, been an ongoing process. The currently accepted explanation, or model, proposes that the spectral differences among the stars are due to temperature differences. The temperature of the star determines which of the chemical elements present is absorbing radiation in the spectrum. In other words, the populations of stars could be categorized on the basis of an inferred temperature (e.g., "O" stars: only H, He, and certain highly ionized metals absorbing; hottest stars; 30,000 - 100,000 °K).

Based on current understandings, only certain kinds of stars appear to be "permitted." These "permitted" stars are so classified on the bases of selected temperatures and luminosities. This idea led directly to the idea of the evolution of stars which in turn produced theories about energy generation in stars.

One advantage of identifying populations is that it enables the researcher to quickly identify objects that don't "fit." These objects are then singled out for special study.

DISCUSSION

COLLINS - In response to the questions regarding the best time line to follow when working with high school students on a concept such as population and whether it would be better to hit it in smatterings or all at once, there are several possible answers. There are certain unifying ideas that should be taught early. One approach might be to use 2-3 weeks to present the basics, then reinforce them with examples as you go through the next year or two. The examples will give the concept depth and meaning.

SLETTEBAK - I would recommend taking examples and developing them in depth - several weeks being spent on each example. In the case of star spectra I discussed earlier, you could even provide the learners with a mix of spectra and let them do their own classification.

COLLINS - Either examples could be integrated into the whole by the learner (inductive approach) or a framework could be provided and then the examples presented, whichever is best for your learners. Each class is unique.

SLETTEBAK - In thinking about learning activities a high school student could tackle relative to the concept of population, the key is involvement. Let students observe the stars. However, be careful not to get into busy work.

COLLINS - Insects are very useful teaching aids since you can have an entire population in a jar. They are small, manageable, inexpensive, and not difficult to maintain. Observation of a population is doable under these conditions. Another type of activity that could be completed is a simple census of different habitats (e.g., comparing a grasslands area with a woodland area). An intuitive feeling for habitat preferences of populations should evolve from this kind of activity. Observation of a simple aquarium might also be a worthwhile activity.

DAVIS - Well-planned excursions are effective, as are games and role-play simulations.

SLETTEBAK - Although the concept of population doesn't come up in every research problem, whenever you have a situation where you have a large number of objects and you are trying to understand the relationships between them, then you have to classify the objects into populations.

COLLINS - We study them primarily for their predictive value.

DAVIS - The concept of populations is the base for human geography.

Problems of Implementing Unified Science Programs

The implementation of unified science programs by local school groups invariably is accompanied by certain persistent problems of a general nature. The prospects of establishing and maintaining a successful unified science program in any one school setting depend to a large extent on how well these problems are coped with by the teachers involved. Five of these problems were selected from a rather indeterminate list for discussion.

Each problem was assigned to two discussion sections. The two sections were not concurrent, therefore, it is possible that any one participant could attend two different discussions of the same topic. However, the chairman and panel were different for each section. The chairmen had the option of making a presentation, as did each panelist.

Each section was charged with identifying specific aspects of each problem topic and with developing some promising approaches to treating these aspects. Participants were encouraged to "blue-sky" in their deliberations as well as to review current practices that have merit.

The summaries of the presentations and accompanying discussions have been prepared by the editors directly from the audio tapes of the full sessions. These tapes, in cassette form, are available on loan from the Center for Unified Science Education. Each tape runs about 80 minutes. In general, the tapes are of good audio quality, except for comments from non-panel participants.

Establishing Objectives

Panelists: *Carl Pfeiffer, Monona Grove (Wisconsin) High School*
Mike Feer, Lincoln-Sudbury (Massachusetts) High School
Ouida Bailey, Lincoln-Sudbury (Massachusetts) High School
Paul Holobinko, Center for Unified Science Education, Ohio State University
Chairman: *Mika Oriedo, Research Associate, Science and Mathematics Education, Ohio State University*

PFEIFFER - The three basic questions which serve as a basis for developing objectives are: 1 - What is it that we're trying to do?, 2 - How are we trying to do it?, 3 - How do we know how well we're doing?. These questions serve as guidelines in linking educational goals to program goals and development. Several assumptions related to objectives underlie the Monona Grove unified science program. First, there is a hierarchy of educational objectives leading to guidelines for program development. Secondly, objectives need to be developed and implemented for an entire school system by groups of local educators, not by individuals nor for separate grades. Thirdly, objectives need to be expressed in writing for common discussion purposes, evaluation, etc.

The hierarchy of goals at the broadest level includes one or several broad general goals for all learners on which there is a faculty consensus, for example, to understand oneself in relation to other people and one's physical environment and to the highest possible level of understanding. At the next level, specific operational goals indicate how the general goal is to be realized by all learners in the system. One example of such a goal is: "to fulfill human needs, such as, a need to develop skills in the use of one's sensory mechanisms and a need to identify and use those ideas that are necessary in order to understand one's self in relation to others and to the physical world." The third level in the hierarchy consists of overall program objectives, e.g., science. Science is considered to be especially relevant in assisting learners to help understand their relationship to the world in which they live. The most specific goals function at the learning activity level and are directed at building a basis for understanding the broad unifying themes of matter, energy, and change.

All levels of the goal hierarchy serve in varying degrees as guidelines for selecting content and learning experiences on a "K-12 continuum of experience."

FEER - The major teacher goal of the Lincoln-Sudbury High School unified science program is to generate an atmosphere in which unified science objectives are realized. The broad goals are:

1. to develop an atmosphere conducive to the apprehension of the totality or unity of the scientific endeavor
2. to develop an atmosphere in which students may also appreciate the contributions of the discrete basic sciences and their relationship to the unity of science. The disciplines compliment each other in a unified science program.
3. to provide opportunities to develop skills that would play a significant role in a rapidly changing and technological environment and in making decisions in such a world
4. to provide interdisciplinary problem-solving learning units to serve as transition from the broader program objectives to unit objectives

5. to create an environment in which students can sense frustration in the scientific endeavor as an integral aspect of thought and experimentation. This frustration can lead to revolutionary science.
6. to blend content intimately with science teaching and social implications so that the student can relate the two to the social-cultural decisions facing him.

BAILEY - The learning units in the Lincoln-Sudbury unified science program are designed to help students to attain the program objectives. An example of such a unit developed for ninth graders is one entitled "Nutriculture." The objectives of this unit reflect the program objectives. Several of these are: to realize a need for basic scientific concepts in solving problems in relation to the study of nutriculture; to develop experiences which challenge the student but not overwhelm him; and to develop decision making capabilities.

Throughout the three months duration of the unit, students are engaged in a number of activities consistent with the unit objectives. These include direct experiences in growing plants to maturity. The unit culminates with student reports of their work and an evaluation of the reports by both students and teachers.

HOLOBINKO - Ideally, objectives should be considered on a school-wide basis, at the program level, and at the unit level. The presentation by Pfeiffer described this approach, therefore, it would be redundant to describe it again. In developing objectives, especially at the program and unit levels, it is desirable to initially aim for "working sets" rather than sets of highly refined or static objectives. Several advantages are gained through this approach. One is that a great deal of time and effort are not expended initially. Insisting on a "finished product" can and does become a block to developing the remainder of the program. Secondly, a working set of objectives is more amenable to change and evolution, hence does not become overly constraining in determining the nature of the program.

In developing objectives for local unified science programs, science staffs have access to a number of resources to assist them in the task. One of these is the NSTA position statement, "School Science Education for the 70's," The Science Teacher, November 1971. Another resource consists of program objectives representing about fifteen different secondary unified science programs throughout the country. These objectives are available as Workshop Module 13 from the Center for Unified Science Education. It is emphasized that these resources should be used as such by local teacher teams in developing their own sets rather than simply adopting any one program's objectives.

A number of problem areas and issues concerning objectives identified for discussion are:

1. Objective format, number, and importance. My position is that small numbers of important objectives stated in terms of learner behaviors are more valid than many objectives of questionable importance cast in terms of what learners are to do or what teachers intend to do.

2. Objectives in the affective domain. Often avoided because of the difficulty in evaluating learners, affective objectives should be included since their very presence serves as guidelines in identifying and selecting learning activities related to the development of affective behaviors.

3. Providing for input into objective development by persons from the community, students, etc.

DISCUSSION - At Monona Grove, Wisconsin, the development of objectives "corporately" for the entire school system at grades K-12 and especially for the science program has resulted in a position agreed on by local teachers. The objectives serve as a basis for evaluating the effectiveness of the program. Also, the process of generating objectives has created much more interaction among science teachers in the system.

There was some disagreement on the role of the student in objective development and selection. One position was that students are incapable of establishing their own objectives except at the lowest hierarchical level, i.e., short range, day-to-day, objectives. On the other hand, it was argued that if students are to learn to establish their own objectives, they must be given the opportunity to do so and assistance in learning how. Another alternative position was that perhaps objectives can be determined by teachers, but that provision can be made for students to work toward them by alternative and personalized pathways.

Evaluation - Section 1

Panelists: *Dr. Thomas Gadsden, P. K. Yonge Laboratory School, University of Florida*
Dr. Michael Fiasca, Science Education, Portland State University
Dr. Stanley Helgeson, Science Education, Ohio State University

GADSDEN - In thinking about evaluation of unified science programs it is important to consider both formative and summative aspects. In formative evaluation, the procedures generally focus on the unit level of work and in summative procedures the focus is on a whole year's work (or greater). Results from the former can best be used to revise parts of the program. Results from the latter can best be used for general assessment.

In general, I see seven major steps in conducting evaluation of unified science programs. The seven can be arranged in a type of flow chart model which is detailed in my Development of a Model for the Evaluation of Local Unified Science Programs (Dissertation Abstracts, Ann Arbor, Michigan, 1971). The seven steps are: 1 - Context Identification, 2 - Optimization, 3 - Design Development, 4 - Implementation, 5 - Analysis, 6 - Reporting, and 7 - Decision-Making.

In the process of identifying criteria, it is important to consider the needs and probable demands of the decision-makers who will be interested in the eventual results. Some of their interests may relate to: the adequacy of the new program and materials, potential for further dissemination, potential for further development and financial support, professional concern for the overall effects of the program, etc. At the same time, it is necessary to consider the realities of the situation in terms of the constraints imposed on the evaluation effort. Mainly, these constraints have to do with limits in terms of available time, money, and development effort.

The second step - Optimization - requires that priorities must be set to determine what merits evaluation out of the myriad of things that could be evaluated. There are some obvious disadvantages of doing this with "internal" as opposed to "external" personnel. For the person working within the program, the task is often complicated by a "Chinese Baseball" situation. That is, by the time an evaluation project is underway, the emphasis within the program is or needs to be changed so that the original decisions regarding criteria, etc., are no longer valid in a technical sense.

Needless to say, there are many alternatives at each stage of evaluation. Among these, and one which I really want to emphasize the potential value of, are non-reactive measures. That is information that can be gathered on the spot. In some ways it represents what used to be called "anecdotal data." This kind of information includes: attendance records, relevant books checked out of the library, parental feedback, etc.

The remainder of the steps go beyond the time available here for discussion but they are not so crucial as the first two steps since these represent the real motive force in getting an evaluation program underway. The last five steps can be handled by following fairly well prescribed procedures in the literature.

DISCUSSION - In developing and selecting tests to accompany unified science programs, the technical concern of reliability can be handled by invoking standard statistical testing procedures and satisfactory levels of reliability can be obtained even for locally constructed tests provided enough time is available to use these procedures. When using commercial standardized tests, satisfactory levels of reliability can usually be assumed. However, the big problem especially when testing for higher levels of cognitive and affective objectives, is that of validity. How does one know that the test items and their results actually reflect that which (hopefully) is being tested?

The usual method of establishing validity is to submit a series of test items that purport to assess certain criteria to a panel of judges who, at least by their professional positions or reputations, are assumed to be knowledgeable about the criteria and to have some experience in similar efforts. Obviously, validity is not guaranteed by this process even when the judges are unanimous in their opinions. The situation is complicated by the problem of deciding what minimum proportion of a validating jury must agree before an item is judged to be "valid" in an operational sense.

FIASCA - Although some "experts" will argue that two different science courses, one of which is innovative and one of which is conventional, cannot be compared directly because they are aimed at different sets of objectives, there is occasionally a need to find what if any differences occur in terms of criteria that represent common objectives. This situation has obviously occurred with unified or integrated science when it has replaced conventional science courses in pilot situations.

~~I my particular~~ study, I attempted to see what if any differences resulted when Portland Project materials were used in place of conventional chemistry and physics courses. The Portland Project materials that were used were those developed in the early phases of the project and which integrated chemistry and physics. These contained none of the biological or behavioral sciences as did subsequent versions.

The subjects of the study were six classes of physics, six classes of chemistry, and six classes of Portland Project. The classes averaged about 25 students each and all were located in the greater Portland area. Tests showed that there were no significant differences among the classes in IQ, science-math background, parental socio-economic background, etc. The specific tests on which differences might be expected to occur were: the Watson-Glazer Test of Critical Thinking, a modified Allen Attitudes Toward Science Inventory, and a combined chemistry-physics achievement test that was developed for the project. All three tests were given pre- and post- at an interval of about nine months. The conventional chemistry class was given <u>only</u> the chemistry portion of the achievement test and the physics classes <u>only</u> the physics portion.

There were no statistically significant differences on any of the test results although the people from the integrated classes showed a slight advantage on their average scores on everything except the attitude toward science test.

DISCUSSION - The FUSE Center has a working file of other studies done on various unified science programs and on the test instruments used by them. One of particular interest is the one done by Victor Showalter because of the test of scientific literacy that was developed for use in the study. In addition, FUSE has almost 100 assorted tests that might be used or adapted for use in evaluating a unified science program.

There is a need for a ready-made instrument that could be used by any unified science program because there is seldom enough time in the usual school schedule to develop or even to select the proper instruments. However, such a test would have to assume a uniformity of objectives that may not exist among the various programs.

Evaluation - Section 2

Panelists: *David Cox, Center for Unified Science Education, Ohio State University*
Dr. William Van Deventer, Biology Department, Western Michigan University
Chairman: *Paul Holobinko, Center for Unified Science Education, Ohio State University*

VAN DEVENTER - My primary interest is in classroom research, of which I have identified three basic areas of concern. These are 1) what to teach, 2) how to teach, and 3) evaluation of teaching and learning. Before embarking upon a study of any of these areas, however, one must decide upon his goals or objectives. Cognitive, affective, and psychomotor realms are all of concern. I have a particular interest in the borderline between the cognitive and affective, which is concerned with the area of understanding of ideas, such as interrelationships, cycles, change, and variation. About 30 such ideas are used in the Idea Centered Laboratory Science (ICLS) program. If you have identified your goals as that of promoting student understanding of such ideas and identified the specific ideas to be utilized, then you can move on to the question of "how to teach."

When dealing with unified science evaluation, you must give some weight to quantitative as well as qualitative considerations. In addition, you must decide upon the balance that you wish to establish between subjective and objective evaluation. Personal preferences enter here; I prefer, for example, multiple choice, best answer, open-ended tests. These are graded by a consensus master (50-80% of the group agreeing with a given choice), which is always subject to modification by the instructor.

In ICLS, an Inquiry Technique Test (ITT) has been developed. It has proven to be both valid and reliable when used in grades 7-9. It is designed to test the understanding of an idea. The first thing done is to ask students to write questions that they believe are relevant to the idea. The idea would have already been introduced, discussed, and one or more relevant laboratory experiences would have been carried on.

With editing and the possible addition of questions by the teacher, you build a list of relevant and non-relevant questions (about 1/2 of each type). Fifty such items are about what a student can handle. A statement of the idea under consideration is placed at the top of the first page, and this is followed by a set of directions. In essence, the directions charge the student to pick out from the list the five questions that he considers to be the most obviously relevant. This process is then continued until 25 such questions have been identified.

This same technique has been applied at the college level, with 50% of the course grade derived from it. At the college level, this type of evaluation is referred to as problem solving, open ended, laboratory.

COX - Considerable research has been conducted on the nationally developed unified science programs, such as <u>Science - A Process Approach</u>, <u>Science Curriculum Improvement Study</u>, and <u>Elementary Science Study</u>. However, there is a need for an increased amount focussed upon locally developed unified science programs. I would estimate that only about 1 in every 15 or 20 locally developed programs has had some type of reported research (e.g., dissertation, journal article, formal paper) conducted. This is not intended to imply, however, that additional local research has not been undertaken. In many instances it may be that action research has been completed but not reported.

Most evaluative studies completed so far are comparative studies, where the unified science program is compared to one or more traditional programs. I believe that there are now enough consistent results that people can move beyond that stage. In general, the studies demonstrate that unified science students achieve as well as, if not superior to, traditional students on tests of subject matter knowledge. In addition, unified science students are usually found to be superior to traditional students in the area of attitudes toward science and unified science programs consistently generate increased elective science enrollments.

If you are in the process of developing a plan to initiate and implement a unified science program, include evaluation as part of your plan. Both formative and summative evaluation in all domains is appropriate.

As I perceive the process, meaningful evaluation can occur at a number of different levels of sophistication. I will suggest four methods by which ~~you may~~ plan to have your program evaluated, even though many more are possibilities. The most important considerations in planning are that you establish a plan that will both satisfy your needs and at the same time be consistent with your local constraints. The four methods are: 1) evaluation by teachers within the program (the university science educator is an invaluable resource for this model), 2) evaluation conducted by a district research or evaluation specialist, 3) evaluation conducted as a result of a contract with an outside educational or research organization (e.g., university, the Center for Unified Science Education [CUSE], regional education laboratory), and 4) evaluation conducted by graduate students (e.g., master's thesis or dissertation).

Expanding for a moment on just one of the sugg[illegible]d models, how would a group of classroom teachers initiate and implement an evaluative study of their own unified science program? They must first have clearly specified science program objectives and then, keeping local constraints in mind, generate the types of questions that will provide answers that the staff would accept as criteria for assessing progress toward achievement of these objectives. Prior to actually implementing an evaluation plan, however, the questions should be evaluated by an outside source, such as the CUSE staff or a nearby university science educator. This would provide some validity check relative to their adequacy as indicators and at the same time allow the reviewing agent to suggest possible additions or alternatives.

The next step would involve the development of a plan for gathering data. As before, consultation with either CUSE, a nearby university science educator, or some other outside agency, should prove extremely useful. There are many instruments available, all or part of which might be helpful. The NSTA publication, Standardized Science Tests: A Descriptive Listing (Wall, Janet and Summerlin, Lee, 1973), and ERIC's Unpublished Evaluation Instruments In Science Education: A Handbook (Mayer, Victor J., 1974) are excellent sources of information regarding instruments.

Following the selection of instruments and gathering of data, an analysis of that data would be conducted. As a result of this analysis, the staff may modify its science program objectives, change learning activities, and/or identify specific areas within the program requiring further study.

Teacher Preparation and Certification - Section 1

Panelists: *Dr. Victor Showalter, Director, Center for Unified Science Education, Ohio State University*
Bernard Miller, Division of Teacher Education and Certification, Ohio Department of Education
Chairman: *Piyush Swami, Graduate Teaching Associate, Ohio State University, science education*

MILLER - Science teacher certification in Ohio and other states is based mainly on tradition. In Ohio, where local school districts are responsible for what is taught in the schools, certification requirements seem to be responsive to demands from the education community. Thus, if there were a sufficiently large demand for teachers certified to teach unified science, and if this demand were sufficiently "loud," such certification would be forthcoming.

In terms of present regulations, in order to teach unified science in grades 7-9, one would require at least a "general science" certificate which involves 30 quarter hours of "course work well distributed over ... biology, chemistry, earth science, physics." In this plan, "integrated physical science course work may supplant basic physics and chemistry courses."

In order to be certified to teach unified science in grades 10-12, one would presently need a comprehensive science certification which requires 60 quarter hours in "an appropriate combination of formal instruction and laboratory experiences," preferably evenly distributed among "biological science, earth science, and physical science." Not too many people currently obtain this certification because in it almost half the total hours needed to obtain a B.A. degree must be in the sciences. Many people feel they must have a second teaching area in addition to science, such as mathematics or social studies, in order to get a job because relatively many two-field positions seem to be open to beginning teachers. The total hours of non-education courses needed to certify in the second field plus required education courses plus university general education requirements, in effect, require a five-year program if comprehensive science certification is also to be obtained.

Ohio and most other states are more flexible than they once were in interpreting formal regulations so long as the problems involve innovative curricular programs and not the question of basic certification in well established fields and in general secondary school teaching.

Teaching unified science "legally" in elementary schools is no problem because essentially the elementary certificate permits all subjects to be taught up through grade 8. (Note Ohio defines "elementary" as grades K-8 and "secondary" as grades 7-12.)

Reciprocal certification with other states is becoming increasingly prevelant and the result, in general, has been to raise required credit hours in substantive areas. FUSE should make its views known more broadly on what constitutes necessary preparation for teaching unified science.

DISCUSSION - The question of whether unified science situations in which team teaching is practiced would be "legal" was raised. The response was that such a decision would have to be made by an "evaluation team," presumably from the State Department of Education.

A question was raised as to whether it is possible for a person to acquire desired levels of competency in specific science subject matter by study "on his own." The response was, "No," although there was an implication that the main reason for this answer was that no other certifying mechanism was available which could replace that of course credit hours.

SHOWALTER - Although there is a very practical need to have a valid teaching certificate when one graduates from college, the problem of what unique kind of preparation is needed to teach unified science persists because no one is certain just what can and should constitute this preparation. The problem has two aspects that, at least for the present, are clearly different. One involves undergraduate or preservice preparation. The other involves inservice preparation which ordinarily would be on the graduate level.

There are some implicit assumptions underlying my comments: 1 - State science teacher certification requirements will not change radically nor rapidly; 2 - College and university course offerings in the sciences will change slowly, if at all, especially when the change would involve three or more departments.

Preparation for unified science teaching must lead to a valid certificate in four years. This could be in any one of the presently certifiable fields provided that the individual also developed a unified science perspective. The latter could be fostered by conducting a special synthesizing seminar conducted by the science education department. The only requirement for the seminar would be that the student be concurrently enrolled in a science course offered by a science department. The learner goals of the seminar would include: a - to develop a view of science as a holistic and humanistic endeavor; b - to develop an understanding of the unique aspects of science as a way of knowing; c - to identify those overarching and powerful concepts and processes that permeate all of the specialized sciences, and d - to recognize variations in the way these concepts and processes are applied in the specialized fields.

This seminar would place the science education department in a cooperative role with students as creative philosophers of science because the focus is really on a science of science. The seminar could also be taught at the graduate level, but the most important factor is that the group be enrolled in a variety of science - ideally the instructor would be also.

The second unique ingredient to be developed should be that of a commitment to and skill in the business of unified science curriculum design and development. Since most unified science programs are locally developed, this commitment and skill are absolutely necessary. In the past, neither has been an integral part of teacher preparation and the focus has been only on how to "translate" or "communicate" effectively an instructional package or textbook that someone else had developed somewhere else.

At the undergraduate level, a start on this second ingredient can be made by inserting appropriate activities in the standard methods course. I believe that two time blocks of two hours each would be sufficient to introduce the undergraduate to the approach to local unified science curriculum development advocated by the Center for Unified Science Education. At the graduate level and/or advanced undergraduate level, a special one quarter course can be conducted similar to that which we developed at the Center last year. The core of the course involved each student developing a unified science modular unit up to the point of actual classroom testing. All sessions of the course were directed to some aspect of this effort.

This particular course involved both graduates and undergraduates. The former were mainly practicing classroom teachers and their units were designed for and ultimately used after the course with their students. It may be that practicing teachers are the most appropriate group for this kind of effort, but somewhere the undergraduate must become sensitive to his or her responsibility in curriculum development and a sensitivity to and awareness of the unified science approach.

DISCUSSION - All unified science programs that have been developed in the past have been done without the benefit of people previously trained in unified science education. The period of development fostered great individual teacher progress in many areas including knowledge of science fields other than their own field of preparation and personal philosophy of education. The best way to prepare unified science teachers, therefore, may be in a group of colleagues dedicated to developing the same program. When schools with well developed programs bring in new teachers, it may be possible to achieve a similar effect by involving them in the ongoing evolution of the program.

There should be more attention devoted to the development of desirable teacher personality characteristics relative to the cognitive aspects that seem to dominate discussions involving preparation of teachers for unified science.

Teacher Preparation and Certification - Section 2

Panelists: *Dr. Robert Howe, Professor and Chairman, Faculty of Science and Mathematics Education, Ohio State University*

Dr. Gary Day, Director of Science, Educational Research Council of America, Cleveland, Ohio

Chairman: *Dr. Michael Fiasca, Portland State University, Education Department*

HOWE - Teacher education in unified science should start at the inservice level because unified science is still at the innovation level. With innovative things, in general, it is better to work with teachers who know exactly what the educational setting is in which the innovation will be introduced. This knowledge cannot be obtained by preservice teachers because they do not know where they will be teaching.

To have a successful unified science program, teachers must: 1 - be well established in the business of working with kids, 2 - agree with unified science philosophy, 3 - know sources of information to utilize in the program, 4 - have access to external assistance in implementing the program, and 5 - be able to get reinforcement for doing a good job.

In many ways, these concerns reflect considerations made by Victor Showalter in Section 1, especially as they are reflected in the course he mentioned on the concept of unified science and methods of implementing it. However, a course like that will have maximum impact only if it is supported on a continuing basis by a source of assistance.

There is some evidence that 60-hours of college course work in two science fields for teachers is an optimum in terms of subsequent achievement by their students. Much beyond this seems to cause "regression." However, it would seem to be a good idea to develop a five-hour science course taught as unified science on a graduate level for teachers.

As a continuing education plan for unified science teachers in a single geographic area, it would be well to apply the "cell concept" utilized in the early and mid-sixties by BSCS. In the plan, teachers meet for a few hours once or twice a month to discuss common problems and their solution.

DISCUSSION - It was generally agreed that a five-year sequence would be necessary if one were to attempt a preservice program for preparing teachers of unified science even though the wisdom of focusing on inservice programs at this point in time was acknowledged. At the very least, undergraduates need to learn about the existence of unified science programs and the roles of teachers in them. Past experience has shown that when undergraduates hear about unified science, they express extremely positive reactions.

DAY - The most successful teachers of unified science do not have a "balanced background," but they do have a positive attitude and philosophy which, in part, expresses the belief that philosophy is more important than content background. However, this does not deny the necessity of content background. It does mean that content background is not <u>sufficient</u> to teach unified science.

Since "choice-making" is important in unified science programs, it stands to reason that prospective teachers should have a considerable amount of choice in their own educational program. One way to achieve this is to introduce "a project oriented course" in science at the college level.

Other desirable courses for preparation of unified science teachers would include the "hyphenated" science courses such as "bio-physics and bio-chemistry" along with ecology and other obviously "cross-cutting" fields. These courses should be highly lab-oriented so they will resemble, at least in this respect, the courses that will be taught in secondary schools.

DISCUSSION - The problem of preservice preparation of unified science teachers is complicated by the fact that during student teaching, cooperating teachers seem very reluctant to permit the student teacher to try any innovations. This is especially true at the senior high level. Junior high schools seem much more receptive. Therefore, it appears that the latter is a much more probable arena for student teachers to try some unified science things.

When a team of teachers from the same school get together to explore the idea of unified science or to undertake the implementation of a program, a broad mixture of backgrounds is very desirable. This assures a variety of perspectives which is necessary to see the many connections between the various specialized sciences. These are often not apparent to a person with a background in a relatively specialized field.

EDITOR'S NOTE - The topic of preparing elementary school teachers either in or for unified science did not arise during the presentations or discussions. This does not indicate that the topic is inappropriate. The omission probably reflects the fact that the principal concerns of the participants were on preparation of secondary level teachers.

Format - Section 1

Panelists: *Sister Ann Champagne, Science Chairman, Powers High School, Flint, Michigan*
Dr. Tom Liao, Engineering Concepts Curriculum Project, State University of New York, Stony Brook
Chairman: *Larry Gabel, Graduate Teaching Associate, Science Education, Ohio State University*

LIAO - Just recently we took the time to put into diagrammatic form the process that we have been using intuitively for some time to develop mini-courses or units that are organized on problem themes. This diagram or model (Editor's Note - see illustration on next page) formalizes the process and represents somewhat of a systems approach to the process. It should have applicability in other situations as in local schools where similar units are being developed. Like other models of this type, it should be used as a guide and not followed blindly.

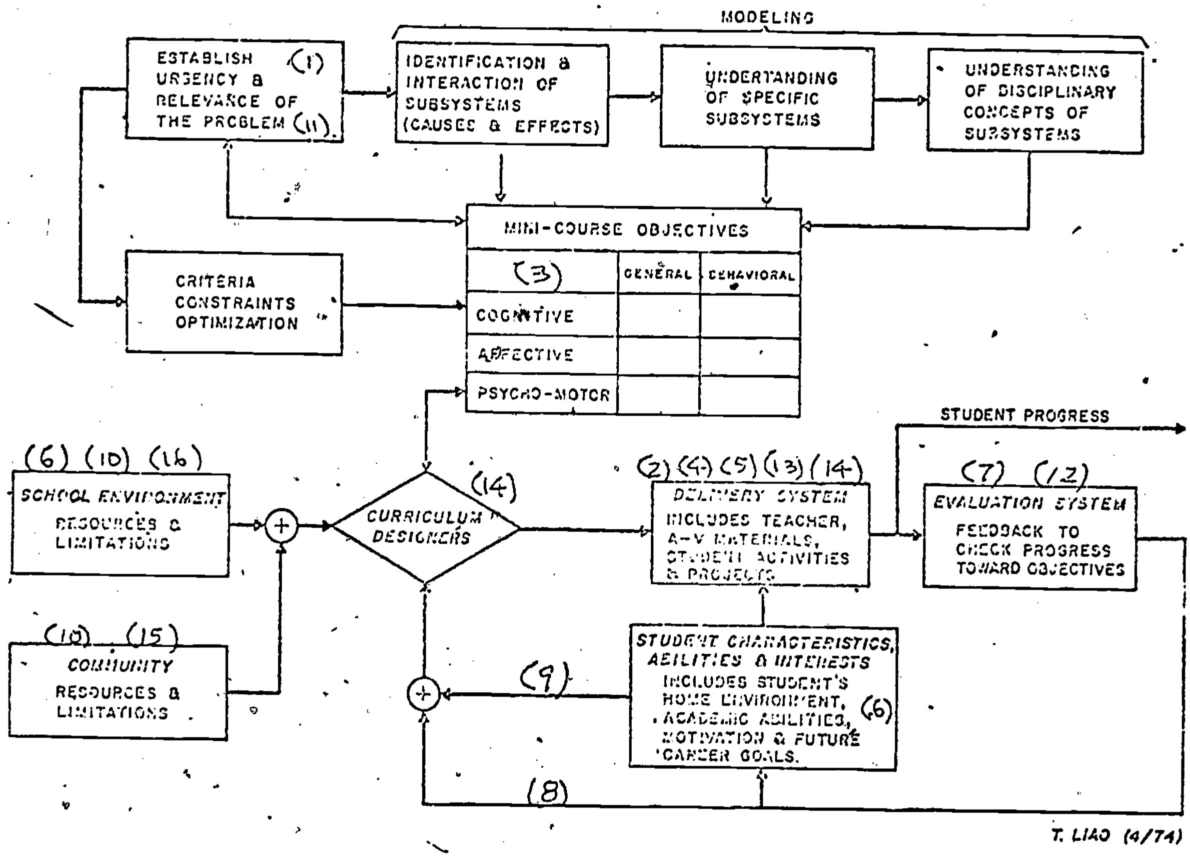
In actual practice, there is a tendency to say, "Let's have a unit on noise pollution" and then attempt to put the unit together without really careful planning. As a result, the unit comes out to be overly general and maybe even to miss the implicit objectives that were intended in the first place. In fact, you can't even just sit down and write objectives for such a unit. There must be some critical analysis and thought that is directed to the situation first. You will note in the diagram that no less than six arrows (inputs) lead into the block representing the actual writing of unit objectives and the selection of learning activities does not occur until the block designated, "Delivery System."

Most of the blocks in the diagram are self-explanatory. The parenthetical numbers refer to the specific guidelines for developing a unified science unit established by the Center for Unified Science Education. There may be an additional block needed at the very beginning and that would read, "Select Problem Theme."

It should be pointed out that the actual format or organization of the "Delivery System" or learning activities is not as important as that they be organized in such a way that they are consistent with the local school facilities and, above all, capitalize on student interests and accommodate local constraints. For instance, many inner city schools have very poor attendance and it becomes necessary that each day's activities effect some kind of closure so that each student will be able to experience a feeling of accomplishment. This may not be so important in a suburban school where absence is a relative rarity but even there some students prefer frequent satisfactions in accomplishment and are unable to see the "rainbow" at the end of a lengthy sequence of learning activities in which satisfaction comes only at the end.

DISCUSSION - There is a problem in this process in that someone is going to have to decide what should be left out of a science program composed of problem based units since it is rather obvious that not all of what has been traditionally taught can be retained along with the introduction of new material. The problem is compounded by the prior question of who is going to make these decisions. There seems to be a growing school of thought that says the local teachers and students should make these decisions assuming that there is some external guidance available. Actually, one of the major goals of education should be to enable students to organize masses of information and, in so doing, to filter out trivia so that one ends up with a nice balance between useful specifics and generalizations.

A MODEL FOR DESIGN OF PROBLEM-CENTERED MINI-COURSES



Parenthetical numbers refer to specific guidelines in the table below.

GUIDELINES FOR DEVELOPING A UNIFIED SCIENCE UNIT

The unified science unit should:

1—be organized around a theme which is either: (a) a big idea (concept) that permeates all sciences, (b) a process of science, (c) a natural phenomenon, or (d) a problem.

2—incorporate learning activities from several of the specialized sciences including one or more of the behavioral or social sciences.

3—be based on a few clearly stated objectives in learner terms and which are consistent with overall program objectives.

4—provide learning activities for 4-8 weeks of usual school time.

5—incorporate a variety of learning modes, many of which include "concrete" experience.

6—be essentially self-contained, yet be an integral part of the local science program. It should be interesting to and usable by learners at a specified grade level.

7—include an end-of-unit test based on achievement of unit objectives and should contain only a few (if any) items of a purely recall nature.

8—utilize a format that will lend itself to continuing evolution of the unit in time.

9—contain opportunities for learners to make some choices of what and how they learn.

10—utilize commonly available equipment and materials, require a minimum expenditure for special equipment and materials, be compatible with local constraints, and capitalize on existing resources.

11—be prefaced by a rationale which is addressed to both learners and teachers and which describes reasons for the unit's importance, interest, etc.

12—include several opportunities for learners to self-check their progress toward achieving the goals.

13—be accompanied by a brief description of the teacher's role in teaching the unit.

14—identify the source of the learning activities used in "building" the unit. Activities adapted from or located in other sources should be clearly linked to the unit.

15—include a list of materials and resources required in the unit and their source or location.

16—be accompanied by an accurate estimate of the man-hours of effort required to assemble the unit.

These guidelines are reproduced from Prism II, vol. 2, no. 1, Autumn, 1973. The original article contains some detailed explanation of each guideline.

CHAMPAGNE - Unified science at Powers has been a "going thing" since the school's inception in 1967. At first, the ninth grade science program consisted of four nine-weeks units or mini-courses that were very loosely organized around a few very general objectives. This scheme proved unsatisfactory for many reasons among which was greater diversity in student backgrounds than we had anticipated. (Powers receives students from a large number of elementary and middle schools which have a wide variety of science programs.)

Our immediate response to this situation was to undertake a serious and in-depth study of those ideas we, the staff, felt that students should understand. After some effort, we were able to get a nominal concensus on ten items.

The format for our unified science program has been that of learning activity packages (LAPS) with multiple texts. However, the culminating course in the unified program consists almost entirely of an individual research project of each student's choice. This course could be the third or fourth for a given student. The project must involve both reading and experimental research and, as a matter of fact, almost always turns out to be unified to the extent that the study crosses the traditional boundary lines of the specialized sciences. For example, one of our fourth year people studied the effects of a magnetic field on growing plants. In this fourth year, each student terminates the study by producing a scholarly paper. In addition, each student presents a seminar for other students and faculty (including non-science teachers) sometime during each nine-weeks grading period.

Although our LAPS have been built on big ideas, I believe they were thrown together too haphazardly. We now seem to be evolving toward FUSE type units. This direction came about as a more or less independent discovery. One of the things wrong with our LAPS has been that the 30-40 objectives for each are too many and tend to overwhelm the students.

We at Powers are still involved in evolving our unified science program. Some of our problems involve teachers who find it difficult to give up their "thing" as represented by a conventional science subject. At first, we were plagued by a lack of acceptance of unified science by General Motors Institute (GMI) which is very influential in our part of the country. But they have done an about-face and now support the concept of unified science.

Format - Section 2

Panelists: *Donald Pegler, Research Associate, Educational Research Council of America, Cleveland, Ohio*
Carl Pfeiffer, Science Chairman, Monona Grove High School, Monona Grove, Wisconsin
Chairman: *Dr. Barbara Thomson, Coordinator, Center for Unified Science Education, Ohio State University*

PEGLER - The ERC Unified Science program is essentially what you saw when you visited Villa Angela. The origin of the program occurred in 1968 when the science staff of Villa Angela came to the ERC science staff for help in designing a science program that would be uniquely suited to the Villa Angela students and which would not only be compatible with but actually take advantage of the new building that was then in the planning stages. Since ERC represented a consortium of about 30 school districts at the time and since the Cleveland Diocese was one of those districts, the Villa Angela staff had ready access to ERC staff.

Originally, the unified science materials were developed cooperatively using both Villa Angela and ERC staff people. Now, however, the development of the materials is done by ERC staff and field testing of the materials is done in Villa Angela and other schools. Coincidentally with this shift, there have been considerable personnel changes in both staffs.

The format of the ERC unified science materials corresponds to the modular unit design advocated by the Center for Unified Science Education. Thus, each six-weeks unit is initiated by an introductory whole-group activity or module. This is followed by students' choosing two or more modules from a selection of 6-15 alternative modules. The unit is concluded with a single-group generalizing module and test. In this plan, students are together at the beginning and end of the unit and individualized in the middle. However, unlike the Center model, each of the modules in a unit is written by staff and not lifted from pre-existing sources.

There are quite a few assumptions about learners on which the ERC program is based. In no order of priority, some of these are:

1. Not all secondary students are past the concrete operational stage of development as defined by Piaget.
2. Secondary school students can assume some responsibility for their own learning provided they are given adequate guidance.
3. Students become bored when only one or a limited number of instructional styles are used.
4. Students enjoy choosing what and how they learn.
5. Success breeds success.
6. Students learn from each other.
7. Learning how information is obtained and organized is more important than merely accumulating knowledge.
8. Subject matter should be interesting and relevant to the contemporary world.
9. Content must have survival value and should be important to the individual in his or her world.

The present state of the ERC unified science materials is still developmental. Following usual ERC policy, the materials will eventually be given to a commercial publisher on a royalty basis. The units are not sequential although they are grouped according to levels.

DISCUSSION - Although the ERC materials do not follow the FUSE dictum that materials be developed by the teachers who teach them, it is felt by ERC that the savings in development time which many teachers either cannot or will not devote to such an effort compensates for whatever value might accrue through "ownership."

PFEIFFER - Our particular program is very highly structured at the present time. That is, on a given day all learners in a given group are probably doing the same thing. However, we are evolving toward a modular organization where there will be more choices for the learner. These choices will not be in terms of what is to be learned but rather in terms of how pre-specified objectives intended for all learners will be learned. Thus, actual format is not nearly so important a question as is that dealing with what is to be learned.

Our unified science program is now organized on a K-12 basis. (Editor's Note - this represents the result of about 12-years of development effort which started in grades 9-12 and then went back to kindergarten, worked upward, and finally completed the K-12 sequence.) Unification has been achieved by establishing a comprehensive set of objectives that are derived from the principal goals of the school system which involve three kinds of relationships: 1 - self-environment, 2 - people-people, and 3 - society-environment. These are first order objectives from which we have derived second, third, and fourth order objectives for the science program. Most of these lower order objectives deal with the self-environment relationships because that is the area in which science seems to have a particular and unique contribution to make.

Second order objectives involve the concepts of matter, energy, and time so that learners may more fully understand the nature and process of change which is universal.

Third order objectives involve sub-concepts and principles that relate directly to the super-concepts listed as second order objectives. Thus, in connection with "matter" there are: structure, general properties, special properties, occurrence, value, etc. Someone else might produce a different list of sub-concepts but we feel ours is very well suited to our purposes.

Fourth order objectives are derived from the sub-concepts listed in the third order list. These fourth order objectives specify a stage in what seems to be a hierarchical series leading to third order concepts and subsequently to second and first order objectives. These fourth order objectives are also matched with levels which correspond mainly to grade levels.

As an example of a third order concept based objective, let us consider "structure" and see how it can be translated into a fourth order objective at several different levels. At Level A (kindergarten), the idea to be developed is, "The apparent size of an object is not always the same." At Level B (first grade), the idea to be developed is, "The appearance of any object depends on the arrangement of its parts." At Level C, the idea is, "A set of objects becomes a functional whole (i.e., system) when the objects are arranged in a special way." The sequence of ideas is continued onward and upward but always contributing to the development of the learner's concept of "structure" as it relates to the "super-concept" of "matter."

Parallel sets of fourth order objectives can be specified at all grade levels for each of the third order concept-objectives. These parallel sets are the vertical threads of continuity throughout the program.

At the present, we provide a selection of many activities that are intended to help students achieve the specific fourth order objectives. It is up to the teacher to select which of these activities will actually occur in the classroom but as mentioned earlier this selection is much less crucial than is the specification of fourth order objectives themselves.

Logistics - Section I

Panelists: *David Cox, Center for Unified Science Education, Ohio State University*
Sister Diana Stano, Villa Angela Academy, Cleveland, Ohio
Chairman: *Dr. Barbara Thomson, Center for Unified Science Education, Ohio State University*

STANO - Our situation was rather unique, since we were able to plan for and implement a changing science curriculum along with a change in physical facilities. The planning for both of these changes was guided by the school's educational philosophy and goals. In essence, we decided to develop a unified science program that could be implemented and function efficiently in an open-space physical facility. The entire endeavor, which is still in progress, has been a most exciting and rewarding experience.

The presence of an understanding and supportive school principal was a most important consideration. Without administrative support, it is doubtful if we could have succeeded in our plan. In addition, we were able to work continuously and cooperatively with the science staff of the Educational Research Council of America (ERC). Much of the reproduction of materials, etc., that would normally have been accomplished within our school was taken care of at ERC.

Because the program was being developed during the school year as well as the summer, we had some trying moments. There were times that the materials arrived only a day or two before they were scheduled to be used, but somehow all of the deadlines were met. It should also be mentioned that we decided to implement our four-year program one year at a time.

The classroom management aspects of our program are often of interest. Our science staff serves basically as resource people, with many different activities occurring simultaneously in an open-space science area. However, there are times that class-sized activities (e.g., discussions) do occur and each student is technically assigned to a teacher for science. Each teacher also has responsibility for recording the progress of the students assigned to him or her. We utilize the modular unit format and, in fact, were the first school to employ that instructional model in a unified science program having received the idea from Dr. V. Showalter who was with ERC at the time.

COX - Rather than discuss logistics in general, I would like to focus on just one aspect in some detail. An area that all development teams, at one time or another, will be concerned with is that of the production of student instructional materials. Even though it is possible to use instructional materials in their regular commercially bound form, it is necessary to prepare at least a few student guidesheets for each unit.

Probably the most important of all considerations in this logistics area is the establishment of a realistic time line. Deadlines for the various components of the materials must be clearly defined and adhered to. Nothing is more frustrating to teachers and learners alike than not to have instructional materials available when needed. More than one new program has gotten off to a shaky start, not because of the quality of the program or preparation of the teachers, but simply due to the failure to plan adequately for the production and distribution of instructional materials.

Experience has demonstrated two things relative to the local production of student instructional materials: 1) it is better to reproduce and collate materials continuously throughout the development period (e.g., summer) rather than all at one time at the end; and 2) proper budgeting of time, personnel, materials, and equipment is essential.

Let's first examine the time line dimension. Having once determined what tasks need to be performed, it is possible to establish reasonable deadlines for the completion of the writing and/or assembling of the various components of the student instructional materials. This allows for the orderly proofreading, reproduction, collating, and binding of the materials. If an effort is made to compress all of these activities into the final two weeks or so of the development period, a number of problems are likely to arise. Among these are: 1) undue stress and demand on typing and reproduction personnel, 2) rushed and therefore unsatisfactory proofreading, 3) unavailability of writers for either proofreading or consultation, 4) undue stress on equipment (even mimeograph machines need to rest!), 5) little or no marjin for unexpected and unavoidable delays (e.g., illness of key personnel, machine break down), and 6) competition for the time of either clerical help and/or machines (especially during the late summer and early fall).

Another important consideration is personnel. Quality typists, machine operators, etc., are essential, and some of the best available people (e.g., students, school secretaries, business teachers) may only be available during limited periods of time. Arrangements for their services must be made as soon as possible.

Finally, materials and equipment must be provided for. Typewriters, mimeograph stencils and/or duplicator masters, mechanical collators, duplicator fluid and/or mimeograph ink, binders, etc., are all necessary and needed at particular times. While it may at first seem best to utilize school equipment, the wear and tear is substantial, and all parties might be better served by the rental of certain pieces of equipment. Also, some severe competition for certain pieces of equipment begins to surface as summer turns to fall.

In addition to the materials and equipment already mentioned, you will need paper. The weight to be utilized, as well as whether or not it should be pre-punched, are important financial considerations.

Last, but not least, you will need to decide how you wish to distribute the product. You may wish to simply hand out three-hole-punched pages and have the learners provide the binders (if so, remember that it is possible to do the reproduction on pre-punched paper), or you may wish to provide binders for the students. If the number of binders required is sufficient, you can obtain both at a reduced price and with a customized cover.

An alternative model is to have mimeographed pages (three-hole-punched) bound by either rings or plastic strips similar to those used on bread packages. A slightly more sophisticated system might have the units bound in report covers or even with a standard glued binding. Perhaps most satisfactory in my own program (Portland Project) was the Velo-Bind binding (A. B. Dick Company). It is inexpensive and has proven to be extremely durable under normal student use. However, with the last two mentioned methods of binding, a great deal of flexibility in implementing changes in order or content of the material is lost.

The intent of this discussion has not been to discourage or scare you, but simply to point out that planning is required and that consultation with the Center for Unified Science Education or others who have been through the development process will probably save much time, effort, and money.

Logistics - Section 2

Panelists: *Dean Hatfield, North High School, Bakersfield, California*
Betty Fahner, Cambridge Junior High School, Cambridge, Ohio
Chairman: *Victor Showalter, Center for Unified Science Education, Ohio State University*

FAHNER - The combined science staffs of our junior and senior high school have been looking at unified science as a curriculum structure that might replace our conventional program especially in grades 7-9. We have a total of eleven staff members and of them, two are unconvinced and another two are definitely antagonistic to the idea. Therefore, we are just at the beginning stages of implementing unified science.

One of the factors that seems to be working toward a decision to go or not to go into unified science is the immediate problem of being long overdue to select a new textbook for ninth grade science. If we can show the administration that the money ordinarily put into buying classroom quantities of texts can be put to better use by implementing a unified science program, we will get support from the administration.

Our biggest problems right now seem to be money and the administration. As mentioned above, the only money available is that which ordinarily would go into textbooks. Also, some of the administrators seem to be afraid of doing anything different. For instance, they are afraid parents will not like the idea of their children not having a textbook to carry because they are in unified science. At the present, we think we will manage that problem by giving each student a durable vinyl three-ring notebook in which they will accumulate the paper materials that will go with the unified science program.

On the positive side, however, the administrators, or at least some of them, would like to see the science program articulated from one grade level to the next, which it certainly is not now but which a unified science approach could help in bringing about.

HATFIELD - We feel our biggest needs have been time and patience. It is absolutely impossible to get anything like unified science implemented overnight. In a secondary school district like ours which is very large and has many high schools, it is very important that each building staff have a large amount of autonomy in determining their own science program. Even so, in our case the transition to unified science is slow. As an example, our unified science units are taught in a course that is still officially titled, "biology."

We feel that the guidance counsellors are a very crucial group of school people to get on your side if unified science is to be a success. After all, if the guidance people do not recommend that students take unified science, you would not have any students and that would end unified science before it really began. Therefore, it is a good idea to keep the counsellors aware of what you are trying to do and let them know that your unified science course is not just a "Mickey Mouse" kind of thing.

DISCUSSION - For many schools that already use or have experience with a multiple text approach, the transition to a unified science is relatively easy because it represents less of a departure from current practice. Not only that, but the multiple texts themselves are a great source of modules for unified science units so there is no need to throw them out.

A good source of both talent and money is the college or university that is closest to your school. The college people have contacts and resources that can really help and, in recent years, have shown increasing interest in working with schools in science curriculum development. They also have experience in preparing grant proposals which can be used to provide the money for implementing unified science. This is important even if unified science can and has been done on relatively small amounts of additional funds when compared to some of the new national programs.

My Unified Science Experience in Retrospect

Panelists: *Geoffrey Cummings, Bank Employee*
Kenneth Thompson, Graduate Student
Richard Wilders, Graduate Student
Chairman: *Herbert Coon, Professor, Science and Mathematics Education, Ohio State University*

COON - During this session, we will hear about some of the impressions that persist today, ten years after our panelists graduated from the University School. In the four years prior to their graduation in June, 1963, they had an opportunity to participate in a unique unified science program. During that time, incidentally, I was principal of the school.

The school itself was unique and had a tradition, since its inception in 1932, of being progressive. The teachers were able and agressive and committed to curriculum development. Although many of the students were professors' sons and daughters, a significant proportion of others were recruited and attended on fee waivers thus giving the school a desirable kind of balance in which minority groups were well represented. Wide diversity in IQ's was also a characteristic of the student body.

Now, we will give each panelist a chance to say something about what he is doing presently and how long he attended the University School.

CUMMINGS - I attended University School from grade 7 through grade 12. I obtained a B.S. in sociology from Ohio State University and am now employed by a local bank.

THOMPSON - I entered University School in grade 9 so I was there four years. I am now completing a Ph.D. program in sociology at Ohio State.

WILDERS - I guess I'm the most experienced University School goer since I was there from grade 5 through grade 12. I obtained a B.S. from Carnegie Tech (now Carnegie-Millen) and am now completing my Ph.D. in mathematics education at Ohio State University.

COON - I wish we could have broader representation on this panel but individuals are always hard to locate after ten years and some that wanted to participate on this panel were unable to be here for one reason or another.

For our first question, let us consider, "What do you remember especially from your unified science at University School?"

THOMPSON - What I remember especially was my individual project on shape recognition by hamsters that I did in the ninth grade. This was generally in the field of experimental psychology and although I can't remember the specific results, I do recall that I felt I gained a tremendous insight into the behavioral sciences.

(EDITOR'S NOTE - The University School unified science program contained one 3-4 week unit in each of the four years that was devoted to students' individual studies. These studies were required to contain empirical data in addition to that from the literature.)

WILDERS - I guess for me it was my physiology project in the tenth grade.

CUMMINGS - Well, for me there were two things. We studied about many of the big ideas in science but there was this unit in the eleventh grade on "Models." It was the most enjoyable and understandable unit and I learned a lot from it.

The second thing was my project on "Boomerangs" that I did in the eleventh grade and in which I am still interested.

WILDERS - Now that Geoff mentioned it, I thought the unit on "Models" was pretty great because it gave you a way of looking at most everything.

COON - Was the University School program really unified (i.e., fused)?

CUMMINGS - Some units seemed less fused than others. Some of the earlier units during the four years were obviously split into sections that definitely were chemistry, biology, etc.

WILDERS - The method or approach used whereby inferences were made from data was very unified. It seems to me that these work about the same way in all science regardless of what special field of science it is.

COON - How do you regard the adequacy of your high school science for the college level work you had to take?

WILDERS - I feel I was very well prepared in how to think and thus was very useful in most of Carnegie's courses all of which were required and formed a fixed curriculum. I did have some problem with chemistry but that was the fault of the course and its instructor. He expected us to know a lot of memorized facts - for instance, we had to memorize a large proportion (maybe all) of the periodic table which was about the silliest thing I had ever done. So chemistry, or really the way it was taught, was a shock. But there was no such problem in physics and I breezed through it.

THOMPSON - I experienced some of the same shock in college where expectations were entirely different. I think the botany course I took consisted entirely of trivia.

COON - For those who aren't knowledgeable about the University School, it should be pointed out that conventional grading systems were not used and this could well account for some of the "shock" reported by these two people.

THOMPSON - I don't think unified science should be judged by its effects in a special school as was the University School. I would like to see what it could do in a college where lecture sections number one-hundred or more.

CUMMINGS - The biggest shock and disappointment to me was that college was a place where I was <u>not</u> authorized to think. My ten hours of geology were an exercise in memorization. My five hours of botany only reiterated Thurber's recollections from the same course earlier in this century. And so, college science was more a disappointment than anything else.

AUDIENCE - How do you think you would have liked traditional science in high school?

CUMMINGS - I never would have elected physics and chemistry. Therefore, I got a well rounded education in science through unified science that I would not have gotten even in college.

THOMPSON - Probably not much difference since I was not very gung-ho in science. Conventional science does not give the learner a chance to see science as a whole or to learn how to think. I think conventional science is oriented to memorization of trivia whether it be in college or high school.

WILDERS - I would have been bored silly. I would have done all right but would have come out of it with a very bad taste in my mouth. Of course, it may have depended on the teacher.

AUDIENCE - Does the "shock" you mentioned earlier really indicate that unified science does not prepare one for college?

WILDERS - There wasn't that kind of problem since I scored 650 on my physics college entrance board exam which I took as a junior.

AUDIENCE - At Monona Grove we have found no disadvantage in our students competing at the college level. In fact our unified science students have done better.

COON - I believe Showalter's study on more than a hundred unified science graduates also showed no disadvantages and several advantages.

AUDIENCE - Do you think you developed an ability to generalize as a possible product of your unified science experience?

WILDERS - Yes, definitely but it was undoubtedly a by-product since I don't remember it being taught directly.

AUDIENCE - Would you say your favorable disposition toward unified science is more a function of the individual projects you did or the intrinsic value of the curriculum?

WILDERS - I'd say the biggest factor was the people teaching it.

AUDIENCE - Does this mean that the teachers could have done as well teaching a conventional course?

THOMPSON - If they had, they would have been labeled "rebels" because they would have been going away from the conventional approaches.

WILDERS - It's hard to believe that these teachers would go the conventional route.

CUMMINGS - I disagree a little. I believe I would not have signed up for any course titled chemistry regardless of who taught it.

(EDITOR'S NOTE - The remainder of the panel discussion revolved generally around the University School's policy of not giving course grades and some consequences of this policy. For example, the senior class president instead of a valedictorian gave the farewell talk at commencement and a faculty letter of recommendation served in place of a class ranking and as a unique type of diploma.)

"A Survey of Unified Science and Enrollments"

by Richard Supinski and Michael Szabo

Richard Supinsky, at the time of writing this paper, was a graduate student in science education at The Pennsylvania State University. Presently he teaches at the United States Military Academy.

Dr. Michael Szabo is Associate Professor of science education at The Pennsylvania State University and was Mr. Supinski's advisor during the study reported here.

High school physics enrollments have been steadily declining since physics was first offered as a separate course in 1890.[1] Causes for the decline have been many and varied. In recent years, interest in other natural and social science courses has grown rapidly, often at the expense of physics enrollments. If the new courses were to continue to grow, and if the current trend in high school physics were to continue, physics enrollments would continue to decline and eventually diminish. Many educators and scientists, however, recognize that physics is important and that something must be done to halt the decline and to increase interest in physics.

One possible solution to the problem of declining physics enrollments is to place physics and other new and traditional science courses into a Unified Science Program. Unified science, unlike separate science courses, views science as a whole, organized around big ideas that permeate all science, with subject matter selected from a broad range of specialized sciences.[2] As new science courses would be developed, their relationship, as with physics, chemistry, biology, and earth science, would be highlighted in reference to a unifying theme or big idea.

In an attempt to determine the relationship of unified science to traditional physics, i.e., physics not purposely integrated with other sciences, and the effect of unified science on high school enrollments, the authors surveyed thirty-one educational sites using a unified science approach.

Utilizing a questionnaire specifically designed for this study, the authors would be able to determine: approximately how long various high schools had unified science programs, the relationship of the number of physical concepts presented in traditional physics compared to unified science, and the impact of the implementation of a unified science program on high school science enrollments.

Sample

Having developed the questionnaire, the next task was to arrive at a sample to whom the questionnaire would be sent. The authors selected a nationwide sample of thirty-one high school teachers and other educators believed to be currently involved in a unified science program at the high school level. Selected from a list of unified science programs as published by Showalter in 1973, the nationwide sample concentrated primarily on those unified science programs existing at the high school level, grades 9-12.[3] These teachers and educators were chosen as, in the opinion of the authors, they provided a most representative sample of educators having experience with both non-unified science and unified science programs. As the number of persons believed to be teaching unified science in grades 9-12 was small, the investigators felt compelled to address the questionnaire to the entire thirty-one teacher sample.

Methodology

Each subject in the sample was forwarded the eight-item questionnaire and was requested to answer each question, if applicable, by checking the block that most appropriately represented the situation that existed in their school. Subjects were requested to add any additional comments they believed necessary to further clarify their response. Having completed the questionnaire, the subject was asked to return the questionnaire to the authors by mail.

Results

Responses were received from thirty of the thirty-one persons (97%) to whom the questionnaire was sent. Of the thirty responses, nine persons chose not to answer the questionnaire for the following reasons: their school did not have a unified science program; their school had a unified science program at the elementary level but not at the secondary level; the school did not start a unified science program as it lost one or more of the teachers promoting the program; the educator was no longer associated with a unified science program at the secondary level; or, as only one school reported, the unified science program was discontinued after one year. Eliminating these nine responses, the authors had twenty-one responses that provided a representative survey sample of unified science programs existing across the nation.

Question one was mainly administrative in nature and was designed to determine how long each school had a unified/integrated science program. In question one, as in other questions, the authors included the words "unified/integrated" as all schools were not unanimous in calling their program "unified." Of the twenty-one responses to question one, seven schools had their program for 2-3 years, two schools had their program for 4-5 years, and twelve schools had their program for 6 or more years.

The emphasis of question two was on schools that had unified science programs that involved less than four years of study; programs in operation for one, two, or three years. Question two requested subjects in this category to indicate if there was any discussion or plans directed at expanding their program; eleven schools indicated their program was less than four years long. Of the eleven schools, three indicated there was no such discussion, with one additional school indicating that their program would be expanded if facilities become available.

Question three concentrated on the attitude of unified science educators toward their unified science program. Subjects were asked to indicate if they were sufficiently pleased with their program to recommend it to other educators. Educationally significant is that all twenty-one respondents indicated "YES" to this question. Perhaps even more noteworthy was the fact that several respondents saw it necessary to add further emphasis to their reply to include such remarks as "very much so" and "strongly in favor."

One of the primary means of contrasting traditional physics to physics involved in a unified science program was to compare the number of physical concepts taught in each program. Responses to question four are tabulated in Table 1. As can be seen, only three unified science programs reportedly involved fewer physical concepts than in traditional physics. More significantly, 11 of the 21 unified science programs entailed at least slightly more physical concepts.

Table 1

Response to question four: Do your students receive as many physical concepts in your unified (integrated) science program as they did in the traditional physics course?

Response	Number Responding	Same Amount	Slightly More	Nearly Twice as Many	More Than Twice as Many
N/A	1				
NO	3				
YES	17	6	8	3	0

Since the problem dealt with high school science enrollments and particularly declining physics enrollments, it was appropriate to determine whether the implementation of unified science could be associated with any changes in overall enrollments in grades 9-12, and specifically the school grade level where physics is traditionally taught in the majority of cases, twelfth grade. Responses to questions five, six, and seven are tabulated in Tables 2 and 3. It was found that 14 of 21 (67%) of the respondents reported an increase in science enrollments in grades 9-12, while 10 of 21 (48%) indicated an increase in science enrollments in the twelfth grade.

Table 2

Response to questions five and six: Has there been any increase in science enrollments attributable to the inception of your unified science program and what is the percentage change?

Response	Number Responding	0-10%	10-20%	20-30%	30-40%	40-50%	50%+
NO	7						
YES	14	3	4	2	0	0	3
(Two not indicated)							

Table 3

Response	Responding	0-5%	5-10%	10-20%	20%+	cannot be determined
NONE	4					
NO	7					
YES	10	0	2	1	5	2

While seven respondents indicated "NO" to questions five and six, two of the seven respondents indicated they already had high science enrollments:

- Dr. Thomas Gadsden (P.K. Yonge Laboratory School, Gainesville, Florida) stated, "We already had reached a saturation point in enrollments. 280 enrollments out of 270 students, grades 10-12."
- Mr. Chesley W. Corkum (Deerfield Academy, Deerfield, Massachusetts) stated that enrollments ". . . remained static -- 80% of the student body."

An additional comment furnished by one respondent was not reflected in the questionnaire, but had a direct effect on enrollments. Mr. Norman Worthington (Monmouth Regional High School, New Shrewsbury, New Jersey) stated that "retention after the second year (10th grade) has been greatly improved. *This year 100% of the students who took Unified II elected Unified III.* Difficult to determine a valid base on which to determine a percentage increase."

Question eight, while not directly geared to enrollments, requested the respondent to indicate whether their pupils studying unified science gave any indication of change in interest, enthusiasm, or attitude toward science. Of the 21 respondents, 20 indicated there was, in fact, a change in their pupils interest, enthusiasm, and attitude toward science; one respondent was uncertain.

Conclusions

From the questionnaire, the authors feel confident in stating the following conclusions for this sample.

1. A significant percentage of schools with unified science programs less than four years in length are discussing lengthening their unified science program.

2. Educational systems with actual experience with unified science are sufficiently pleased with their program so as to recommend it to other educators.

3. A unified science program, in addition to including other sciences, can have at least as many physical concepts as does a traditional physics program and will more likely (11/17 or 65%) contain slightly more physical concepts.

4. A unified science program apparently, in at least 67% of the cases, directly contributes to increased science enrollments in grades 9-12. Moreover, where enrollment increases were reported, the increases varied anywhere from 10-50% or more, with at least a 10-20% increase being the most common.

5. There is approximately a 50% chance that those schools having a unified science program will also have an increase in twelfth grade science enrollments. In those schools that reported an increase in twelfth grade science enrollments, the increase ranged from 5-20% or more, with 20% or more being the most common. This finding is particularly significant as the authors were unable to locate any substantial evidence of increased enrollments in twelfth grade science.

Based on the above responses, it can be concluded that unified science does offer a viable solution to declining enrollments in high school physics. As it has been shown that a unified science program may entail at least the same number of physical concepts as in the traditional physics course and that unified science will lead to increased science enrollments, science educators should consider the merits of unified science.

While the sample included essentially self-selected school projects with generally outstanding educational facilities and programs, the respondents were reflective of a nationwide interest in unified science.

The authors are not insisting that unified science is "the solution" to declining physics enrollments, but are suggesting that unified science may have extensive application to current trends in secondary school science. It is likely that unified science will provide science to a greater percentage of high school students.

END NOTES

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3. Ibid. Pages 12-36.

"This Past Winter, We Spelled 'Unified Science': S-N-O-W!"

by Lowell Kleppe

Lowell Kleppe did his undergraduate work at Luther College, Decorah, Iowa, and has obtained Master's degrees from Vanderbilt University (physics) and University of Wisconsin - Superior (science teaching). He presently is science chairman of Ridgemount Junior High School in Wayzata, Minnesota, and has 14-years of teaching experience.

Mr. Kleppe has published articles in Journal of Health Physics and Proceedings of the International Conference on Thermoluminescent Dosimetry.

A persistent problem in Minnesota during the winter months is our natural phenomenon: "SNOW."

For years, we had trudged through the depths of mechanics ... for 2 weeks ... heat ... for 2 weeks ... optics ... for 2 weeks ... sound ... for 2 weeks, and so forth, and so forth. This year, after traveling "cross-country" in search for something new and different, we found a new vehicle for teaching. This new vehicle was not the snowmobile ... but it was SNOW.

"Snow" as a topic for consideration has served as our initial experience with the unified science approach.

Students were writing "SCIENCE IS FUN!" with tempera paints in the courtyard of our school ... and then spent the time until the next snowfall measuring how much each color melted into the snow-covered ground in an effort to study heat-absorption by different colors of paint. Students captured "snowfleas" in the melting snow along the third-base line of the baseball field. White "snow moths" were observed, captured, and brought in for mounting.

Snowflakes were caught on microscope slides coated with ethelene-dichloride and polyvinyl resin that preserved the flakes for later observation and classification under microscopes in the classroom. These were in turn photographed using a Polaroid camera mounted on a microscope. Classification was done by comparing the photographs to the classical snowflake photographs taken by Bennett in Vermont over a forty-five year period.

One boy measured the daily temperatures inside the north, south, east, and west sides of trees and telephone poles in an effort to determine the mechanism of the melting that had been noted around the sides of trees.

A large snow-fort was dug into a snowbank in the parking lot of the school ... first for the experience of doing it ... and then to measure the insulating properties of the snow. (This "fort" was actually too comfortable, and was finally destroyed when some of the more innovative students started to use this facility for a smoking room during their noon-hour break.)

Snowbank cross-sectional temperatures were measured; building expansion cracks were located and evaluated; trees were tapped for sap and syrup was made; colored papers were studied for heat absorption and reflective indices; archetectural considerations for our area were investigated; snow was made by using aspirators and compressed air; the Sasquatch of Northern California and the Abominable Snowman of the Himalayas were studied and the list could go on totalling more than 100 activities actually attempted and completed by the students.

This was our first experience with the unified science approach. It was done by one teacher ... with about half of the ninth grade students in the building. Although he had seen other programs in operation, this was his own version of unified science and was his own format. He used materials that were readily available ... and no new equipment or materials were purchased for this particular unit.

Instead of the psychologically frustrating practice of writing out everything that was going to be done ahead of time, the teacher just started and let the kids go. The kids' ideas were often a surprise and often turned out to be the best ideas of the unit.

There was no attempt to keep all of the students together but there was a definite attempt to keep them aware of what their fellow students were doing. Any "lecturing" was held to a minimum and consisted of informing all of the students of the type of activity that the rest of their classmates were doing and how they were doing it. Some of this was done by teacher lecture and demonstration, and some of it was done by oral reporting by the student involved if he was in that particular section.

A series of 3 x 5 cards were prepared listing all of the activities that were currently being studied and students wishing to do an activity could search through the cards and find one that was of interest to them.

Most of the better units, experiments and demonstrations from the topics on heat, climatology, and meteorology that had previously been a part of this course, were actually included in the new unit although the students felt that they were working all the time with a unit on SNOW and were not working out of a given text. They did refer to a text that was kept available in the room, but it was not checked out to the students individually. The students did make better use of the library facilities than any class had in recent memory, and they did get familiar with the Handbook of Chemistry and Physics in the classroom.

The method of grading was a bit different from the type that had been used before and might be worth mentioning. Quality as well as quantity was used in order to prevent some students from getting top grades on volume of activity alone. In order to get an "A," unusual quality and quantity needed to be present. A "B" could be obtained by either exceptional quality or quantity. "C's" were given when the quality and quantity were average, and a "D" was given when the activity of the student fell substantially below this average. No "F's" were given, but a "U" was sent home with a few of the students who absolutely refused to do a thing during the quarter. This group amounted to about 5% of the students-but much to my surprise and delight, they did not present any unusual discipline or behavior problems during the quarter.

Students were required to have a pass when they were away from the room so as to conform to school procedures in this matter. In addition, each of the students outside of the room were to have a brief statement of what they were trying to do and accomplish on their passes. This seemed to keep them more in line and also kept their objectives in front of them. This relieved us of some of the problems that had been anticipated with the school office and with other faculty members.

At the present time, the kids are working in a unit entitled, "Force and Flight." They are building kites and gliders and are into Bernoulii's principle, Newton's laws, sail-loading, theodolites, tangent ratios, boomerangs, methane balloons, center-of-gravity, gyroscopes, Amelia Earhart, and Charles Lindberg. They really seem to be enjoying themselves and they are able to work at their own rates with the facilities and equipment that we have available. They don't have to sit through boring lectures and don't have to wrestle with the mathematical abstractions that Piaget and others seem to think the student can't really cope with anyway. The kids seem happier and their teacher feels better too. This type of approach seems to be the best one suited to the junior high school level.

Acknowledgements

The author is indebted to Dr. Victor Mayer and Dr. Victor Showalter of Ohio State for exposing him to the ideas and mechanics of the unified science approach. Mr. Joe Premo, Science Consultant for the Minneapolis Public Schools, gave encouragement and shared his offices and materials during the author's sabbatical leave during the first semester of this past school year. Mr. Keith Dodd of Glenrock, Wyoming, suggested a very simple but workable system of grading when working with a new program within the confines of a traditional grading system. Finally, the author wishes to thank Mr. Jack Delaney for reading this paper for him at the FUSE Conference.

"A Course in Unified Science Curriculum Development"

by David Cox

David Cox is presently a Graduate Research Associate with the Center for Unified Science Education. He is on leave of absence from his position as science chairman at Rex Putnam High School in Milwaukie, Oregon.

Mr. Cox has had extensive experience in the development, teaching, and adaptation of the Portland Project unified science materials. He also has considerable experience in disseminating the concept of unified science education in teacher workshops.

This particular course was developed specifically for in-service science teachers and designed to prepare them to develop their own unified science programs. To the best of my knowledge, this is the first course of this type that has been conducted.

Offered under the group studies option within the Department of Science and Mathematics Education at The Ohio State University, the course was titled Studies in Unified Science Curriculum Development for Secondary Schools (Ed: Sci-Math 694.27). Its initial implementation was during the Fall Quarter of the 1973-74 academic year. The course carried either 3 or 5 quarter hours of graduate or undergraduate credit. Those completing the basic course earned 3 hours of credit. Students desiring the full 5 hours were required to complete an additional project which will be discussed later.

The course was initiated in response to an expressed need on the part of Columbus area science teachers. The group studies option enabled course sign-up procedures to occur with a minimum of red tape. The course was advertised only through a mailed flier and by word of mouth. The course objectives are specified below.

As a result of his/her experiences in the course, each student will:

1. Increase his/her ability to describe a rationale for unified science education
2. Develop his/her ability to design modular units appropriate for use in a unified science program
3. Extend his/her knowledge of the concept of unified science education and the various programs that have been and are being developed in the U.S. and other countries
4. Develop feasible techniques for initiating a unified science program in his/her own school setting
5. Achieve to his/her satisfaction any other personal objectives relative to unified science education

The course requirements were:

1. Design and develop a unified science modular unit up

to the field test stage. The unit should meet all criteria specified by the Center guidelines.

2. Write a final examination based on the course objectives.
3. Abstract and code 10 modules of such a selection and quality as to be appropriate for entry into the Center's module bank (e.g., a brief description of a potential learning activity for a unified science unit, including such information as the source, time required, mode of learning, and degree of development).

Those students who desired five quarter hours of credit were required to complete one of the following options.

1. Write 25 additional module abstracts
2. Develop a second modular unit
3. Conduct a field test of the modular unit developed (during Winter Quarter)
4. Develop a workshop module (e.g., a basically self-contained learning package, requiring approximately 30 minutes of user interaction, concerned with some aspect of unified science education; it would become a resource of the Center for Unified Science Education)
5. Other, with instructor approval

Twenty students enrolled in the course, which was offered during the evening hours; most were inservice teachers from the Columbus area. Instructors were Dr. Victor Showalter and Dr. Barbara Thomson, but contributions to both the design and conduct of the course were made by all staff members of the Center for Unified Science Education including Paul Holobinko and myself. Frequent use was made of the resources of the Center.

Special mention deserves to be made of the philosophical approach to establishing and specifying objectives for this course. Each objective is viewed as a continuum. An effort was then made to take each learner where he was and provide learning experiences that would allow him to make progress along each continuum. The objectives are specified in such a way that making progress, any reasonable amount of progress, entails achieving them. Regardless of entry knowledge, all learners can still make progress along each objective continuum.

A pretest was administered during the first class session to place each learner on an arbitrary 0-10 scale for each of the first 4 course objectives. Two test items were constructed for and keyed to each of these objectives. The scoring of the responses to the items was accomplished using the same techniques that were used by judges of diving and gymnastics competitions. Four Center staff members heard each response read by an impartial reader to guarantee the anonymity of the writer. On signal, each staff member held up 0-10 fingers representing the point on the continuum that seemed to be justified by the response. The high and low ratings were discarded and the mean of the two remaining calculated. The mean was accepted as the writer's placement. While not a perfect mechanism, both staff members and students who heard about it later felt it to be very satisfactory.

No student was placed at zero on any continuum and, as expected, neither was any student rated at 10 on any continuum. Great diversity in continuum placement on the various objectives existed, both for the class as a whole and for individual learners. In effect, we developed an initial course profile for each learner in terms of four dimensions or objectives.

The learning activities for the 12-week course were designed and/or selected to enable each learner to achieve each objective. The full human and physical resources of the Center were employed. Since the course itself was intended to convey some of the message relative to the spirit of unified science education, care was taken to provide diversity in modes of learning and alternatives for the learners. The general topics covered are listed below.

1. Introductory activities (pretest, introductions, discussion of course objectives, discussion of course requirements, and course overview)
2. Rationale for unified science education, including guidelines for unit design
3. The modular unit as the basic component in designing unified science programs; abstracting modules
4. Modular unit design and development
5. Types of unified science programs
6. Writing objectives at the unit level
7. Evaluation procedures
8. Alternative modes of learning
9. Strategies for implementing unified science programs
10. Presentation of modular units developed by class participants
11. Concluding activities (posttest and course evaluation)

Among the diverse modes of learning used in conducting the course were reading, field trip, audio tape, slide tape, lecture, small group discussion, simulation, and writing. Some class sessions were held in a traditional classroom while others were held at the Center for Unified Science Education where a wide variety of resources provided many options for students.

Grading was based upon the course objectives and requirements. All learners who achieved the course objectives and fulfilled the course requirements received a grade of "A."

The fact that all activities in the course were directly related to producing a final product that each student would use in his or her teaching had several extremely positive effects. Several of the students commented that this was the first education course they had which was really relevant to the business of science teaching. Others felt that things which had previously been encountered but in a detached-from-reality way (e.g., Bloom's Taxonomy of educational objectives in the cognitive domain) now made some sense and were, in fact, viewed as being very important and useful.

Center staff and participant evaluation of the course indicated that it was a valuable learning experience for both staff and participants. Further, it provided a feasible model for local dissemination of the concept of unified science education. Several unified science programs have evolved in schools that had single staff members participate in the course and many continuing Center-inservice teacher relationships were initiated.

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"Current Issues in Man Centered Science" (Abstract)

by William Van Deventer

Dr. Van Deventer is Professor of Biology at Western Michigan University and was one of the founders of FUSE. He currently serves on the FUSE Board of Directors. He is the primary author of Idea Centered Laboratory Science which is a unified science program intended for the junior high school.

NOTE: This abstract is based on notes taken during the presentation and from a handout addressed to prospective students.

The official catalog title of this course is "Current Problems in Biological Science" and is numbered "Biological Science 107." Nevertheless, the problem areas to be dealt with are the problems of mankind and therefore cannot be limited to one science discipline. The unified aspect of the course is apparent from the unit titles:

1. The Population Problem
2. The Energy Problem
3. The Food Problem
4. The Problem of Health and Disease
5. Water, Materials, and Other Possible Limiting Factors for Man
6. When Is the Human Embryo Alive?
7. The Problem of Heredity and Environment
8. The Operation of Natural Selection
9. The Possibility of a Balanced Environment for Man
10. The Problem of Science and Religion

The principal "big ideas" developed in the course are: Liebigs Law of the Minimum, conservation of matter-energy, food web, differential growth rates, development as a function of heredity and environment, balance in the environment, etc.

The course meets for two two-hour periods each week for one semester. There are two lectures in these time blocks plus time to ask questions and work on problems. The latter is regarded as laboratory work.

There are six tests, each of which is of the "take home" variety and are of a "problem solving" nature rather than factual recall. The student's final grade in the course is based on tests, attendance record, and "any other achievements."

Strong emphasis is placed on textual materials in newspapers and news-oriented periodicals rather than a particular book.

"Using a FUSE Approach with Students Having Reading Problems" (Abstract)

by Betty Jo Montag

Betty Jo Montag has worked in developing a unified science approach since 1964. She teaches at Cupertino High School, Sunnyvale, California. This school contains grades 10-12 and Science I is required of tenth graders. The school also offers conventional science courses to its 1600 students.

> NOTE: This abstract was prepared from a tape recording of the original presentation and its subsequent discussion involving conference participants.

Although Science I has been established for several years, it is frequently changed to meet evolving needs of the school population. The most recent modification has been to develop special materials for those tenth graders with reading difficulties. The latter was more or less operationally defined as reading at a standard sixth grade level or lower and which included about 20% of the tenth grade students.

This modification was in response to a recently established school-wide policy to direct increased efforts to improving reading levels among students. The resulting modification took the form of editing out polysyllabic words and compound sentences from textual material for Science I and which had been written locally in the middle 1960's. There were also special efforts made to practice certain classroom procedures to develop reading skills and the students with reading problems were segregated into special "R" sections of Science I.

Some of the special classroom procedures included word drill, making all tests of the essay type, grading tests, lab reports, etc., for English grammar and word usage as well as for science content, etc.

The modifications have apparently produced results in the desired direction. There may be developing increased student interest in taking more science courses which augments the upsurge of interest provoked by the introduction of unified science several years ago. The apparently obvious solution of creating Science II, however, is slow to materialize because of the reluctance to move in this direction by a minority of the science staff which numbers a total of nine persons.

Most of the reluctance appears to be coming from several biology teachers who feel that even three years of unified science will not convey as much biology as one year of a conventional biology course. Nevertheless, the majority of teachers feel that a modular-unit design could be used to advantage if it were done properly and if the staff could obtain unanimity on the desirability of unified science in general.

"The Origin of Life: Some Educational Aspects"
(Abstract)

by Antonio Lazcano-Araujo

Professor Lazcano-Araujo works as a member of the Faculty of Sciences, University of Mexico.

NOTE: This abstract is based on the paper submitted by Prof. Lazcano-Araujo.

The origin of life is identified as "one of the most appealing and active fields of scientific research of the present time." At the same time, it can be shown that recent understandings in this area have not become an integral part of undergraduate education although there are some notable exceptions to this generalization. This situation persists even though there are an increasing number of books and other media that treat recent advances in the field.

The situation seems to warrant a fusion of heretofore separate academic subjects. In this respect, C. Ponnamperuna is cited as believing that "chemical evolution is a cornerstone in the understanding of processes that gave origin to the first biological systems and which has (tended) to draw together scientists of varied disciplines from microbiology to astronomy."

Therefore, the general topic of "The Origin of Life" appears to be a promising "educational approach to unified science." This theme could be developed in a course consisting of eight units:

I - Historical Background
II - Definition of Life
III - Origin of the Chemical Elements
IV - Origin and Evolution of the Solar System
V - Evolution of the Planet Earth
VI - Chemical and Biochemical Evolution
VII - Biological Evolution
VIII - Exobiology

For teaching purposes, it is important that there be appropriate supporting laboratory experiences. Many of these presently exist and can be drawn from existing educational literature. In addition, students should experience some of the original literature dealing with the problem of the origin of life.

At the present, a seminar is being conducted at The University of Mexico which attempts to use the origin of life theme to promote correlation with and synthesis of other science courses being taken concurrently by the students involved. This approach has been very successful in terms of student interest and may well be a stepping-stone to a full-fledged course.

Some disagreement was expressed that the concentration on word meanings was the best way to solve the reading problem. Instead, it was felt that a major effort should be made to teach students to transfer and to interrelate those things they were able to read. This suggestion was made in the light of a consensus observation that this problem was the major block to learning in science (and other fields as well).

"Initiating a Unified Science Program"
(Abstract)

by Dean Hatfield

Dean Hatfield is presently a member of the science staff involved in initiating a unified science program at North High School in Bakersfield, California.

NOTE: This abstract was prepared from a tape recording of the original presentation and its subsequent discussion involving conference participants.

North High School contains grades 10-12 and is one of thirteen high schools in the Kern County Secondary School District covering an area greater than that of Massachusetts, Delaware, and Rhode Island combined.

Six years ago an effort to integrate science courses was initiated at North High School. A combined "Chem-Physics" course met with some success (unspecified), but a combined "Bio-Chem" program (actually separate courses) left teachers and students dissatisfied. None of these courses generated excitement or high interest among students. The general science approach for non-college bound students did not fare any better.

This was the status of the science program until two years ago when the State of California passed a law requiring a biennial evaluation of teachers in the areas of student progress, personal competency, adjunct duties, and proper control of the learning environment. Continuation of teacher tenure will be determined by this evaluation. Many teachers view passage of this law as an expression of the public's loss of confidence in school personnel.

The reaction of North High's science staff to the perceived loss of public confidence was to consider a unified science approach with its primary goal of scientific literacy as a vehicle to regain public trust. A unified science approach is equated with rigorous or "hard" learning by at least part of the staff, and it is hoped that the rigorous learning required of students will favorably impress parents.

A number of actions initiated by science department chairman, Bob Newbrough, sparked and maintained the staff's interest in unified science. These included participation in a FUSE unified science workshop at Berkeley, a subsequent enthusiastic and informative report of the workshop to other staff members, a working visit to the Center for Unified Science Education, a visit to an ongoing unified science program, and convincing the Board of Education to appropriate funds for a week long working session during which the staff, aided by consultants from the Center, would further investigate the idea of unified science and develop a local "position." This was the first time money had been alloted for this kind of curriculum study.

The North High unified science program is considered to be in its embryonic stage, and it is planned to be developed gradually, that is, in a metamorphic way. During the initial week-long working session, the presently used instructional materials and activities were examined but from a unified science and student fram of reference. The plan is to incorporate these materials into unified science units and these units into the tenth grade biology course until it evolves into a full fledged unified science course. Plans then call for unified science courses for grades 11 and 12 to be developed during the following two years. At least two other high schools in the same district are committed to developing unified science programs.

Predictably, obstacles and problems have been encountered by the unified science team. Among these are: difficulties in obtaining a block of "released" time to work as a team, the influence of tradition in resisting change, and finding ways to develop new teacher competencies. In response to these problems, a decision was made to involve in the development of the units, all teachers who will teach unified science and to apply the work of these teachers as are college credits in determining salary increases. Also a decision has been made to maintain a conventional discipline-centered science program along with the unified science program.

"A Comprehensive Problem Solving Curriculum"
(Abstract)

by Michael Fiasca

Dr. Fiasca was one of the prime movers of the Portland Project which attempted to integrate PSSC Physics with Chem Study or CBA chemistry starting in 1963. He also worked with the subsequent integration of biology to the physics-chem in 1967 to form a three year program. He is currently a member of the FUSE Board of Directors and is Associate Professor of Science Education at Portland State University.

NOTE: This abstract was prepared from Dr. Fiasca's presentation notes, from other notes made by other conference participants, and from subsequent discussion by participants.

Comprehensive Problem Solving (CPS) represents a natural step from previous curriculum work although it may not be appropriate for all students nor for any student all of the time.

A basic premise of CPS is the belief that "students must be given the opportunity to tackle real life and community problems." Further, a student "learns about the disciplines as he needs to know about them as he pursues a problem."

Schools should be "providing adolescents with skills to: perceive and define real problems, collect data, make data analysis, pursue (the problems) in a cross-disciplinary manner, suggest solutions, try them (the solutions) if feasible."

Such a program would enable learners to become more involved in the process of schooling and would not be simply receptors of "predigested wisdom of experts."

An example of such an approach can be found in the Unified Science and Mathematics for Elementary Schools (USMES), although the title of the program is a "misnomer." Sample units in this program are "Lunch Lines," "Pedestrian Crossings," "Soft Drinks," etc.

Questions raised and discussed although not resolved conclusively are: "What is 'real' to learners?," "How does this approach differ from the nearly extinct CORE approach of the 1930's?," "What evidence is there that this approach could enable learners to achieve all aspects of scientific literacy?," etc.

"The ERC Unified Science Program"
(Abstract)

by Gary Day

Dr. Day is Science Department Director and unified science program coordinator at The Educational Research Council of America in Cleveland, Ohio.

NOTE: This abstract was prepared from a tape recording of the original presentation, its subsequent discussion, and materials describing the ERC Unified Science Program.

The ERC Unified Science Program presently consists of eleven modular units and will eventually have thirty units. Each unit is designed to help students progress toward the goals of the program. These goals are all related to scientific literacy. The two basic types of unit themes are "The Big Ideas of Science" and "Science-Society Principles." Each unit will further the development of the students' understanding of these areas. Some unit themes will be selected from these two areas while other unit themes will be selected from concepts or persistent problems. The existing units developed for grades 9-11 are listed below. By September, 1974, all these units will have been revised, two new units produced, and an evaluation program initiated.

Unit Titles

Asking Questions or Starting Inquiry
Perceiving My World
Mind Expanders (Instrumentation)
Making Sense (Interpreting Data)
Experimentation
It's Time for a Change
Systems (Let's Get It All Together)
What's the Matter with Energy (Energy Sources)
Fooling Around with Mother Nature (Ecosystems)
The Down-the-Hill-Gang (Equilibrium)
Patterns

By September, 1975, five additional units are scheduled for completion and field testing initiated. Also, a science literacy test will have been developed. Eventually, the entire program (30 units) will be field tested and hopefully sold to a publisher for publication and national distribution.

The ERC Unified Science Program is intended for learners with diverse abilities, experiences, interests, and aspirations. It is seen as being appropriately used in a variety of ways. For example: individual units can serve as minicourses; units can be used in combination with discipline-centered course materials; one school uses the "process" oriented units with twelfth grade non-science oriented students; single units can be studied for varying periods of time ranging from six to nine weeks; a variety of unit sequences is made possible by using provided "resource" activities designed to help students learn skills, etc., when the need arises.

To-date, only Villa Angela Academy, a four-year Catholic high school for girls, has used the entire program as its only science program. (Eleventh and twelfth grade students study the same units.) About ten other schools are using parts of the present program in the various ways already described.

"Implementation of a Three-Year Unified Science Program"
(Abstract)

by Ouida Bailey

Ouida Bailey is science department chairman at Lincoln-Sudbury Regional High School in Sudbury, Massachusetts, where she has been instrumental in the development of a local unified science program.

NOTE: This abstract was prepared from a tape recording of the original presentation and its subsequent discussion involving conference participants.

The primary goals of the Lincoln-Sudbury unified science program are to involve students in decision making in problem solving situations and to develop a unified view of science. At all levels there is an emphasis on the development of skills necessary in dealing with problems. Although the program spans grades 9-11, this presentation describes units from only the first two grades to show how learning experiences involving scientific concepts are applied to problem solving.

Although decision making, data source identification, data gathering, and the design of courses of action are largely the responsibility of students in problem solving situations, the understanding of related concepts is considered most effectively attained by "traditional investigative methods." A tenth grade physics unit uses electrical, magnetic, and optical phenomena to develop related concept understanding.

A chemistry oriented unit is designed to help students develop an understanding of the kinetic molecular theory. The underlying concepts of this theory are applied to the study of meterological phenomena and to the mechanics of human respiration and blood pressure. A study of the periodic table of chemical elements concludes this unit.

Concepts presented in the above units are applied to "real-life" problem solving situations. For example, the mechanics of breathing are based on the gas laws. Concepts presented in the chemistry unit are applied to a study of blood composition, typing, clotting, etc. Appropriate concepts are applied to understanding cardiac functioning, human eyesight, and photosynthesis.

In the ninth grade a unit titled "Nutriculture" integrates the study of chemistry with plant growth. The learning outcomes are then applied to individual garden plantings to achieve maximal plant growth.

Students are involved in a variety of teacher-student activities intended to develop a better working relationship. For example, students assist in identifying problem situations and the development of related instructional materials. Students are urged to make use of "outside" learning opportunities such as computer studies and plant studies at local universities.

Students enrolled in the unified science program are described as "average and above average" with the latter making up about half the enrollment. A conventional discipline centered science program is offered as an alternative to the unified science program.

Villa Angela Unified Science Program (Cleveland, Ohio)

High on the list of questions asked by people who are introduced to the idea of unified science education is, "Where can I go to observe a unified science program operating in a school?". Largely in response to this question, the annual FUSE Conference has been located near such a school. This year the Columbus location has made it possible to select Villa Angela Academy in Cleveland, Ohio, as the school in which an ongoing unified science program could be visited and observed. Villa Angela is a Catholic high school enrolling about 700 females in grades 9-12.

Since the trip to Villa Angela Academy took several hours by bus, the time spent riding enabled several of the program's developers to discuss the program's background with the visitors in small groups. Samples of instructional materials were available for examination. Thus, a number of questions were asked, most of which were answered by the actual visit to Villa Angela.

The three year (grades 9-11) Villa Angela unified science program was found to be unique to most of the visitors for several reasons. First, the instructional materials are organized in a modular unit format, and second, the school building, which is new, has an open area design for which several architectural awards have been given. A third unique feature is that the unified science program and the building were deliberately designed to complement each other.

Visiting activities were organized in a modular unit format. Brief orienting remarks were followed by "alternative" activities designed to make the visit fruitful. Choices offered included student guided tours of the school, science area visitation and talking with students and teachers who were "functioning as usual," examination of instructional materials, and the handling of logistics. Most visitors chose to participate in several of the alternatives.

The mix of students (grades 9-11) working in an open area facilitated interaction between the visitors and students. Simultaneously, some students were "taking" tests, others were conducting various activities organized around the idea of ecosystem, and older students were organizing modular units around unifying themes of their own choice for independent study.

Since the actual visiting time was limited to about two hours, the generalizing or follow-up discussion occurred during the return bus ride. Sister Diana Stano, science department chairman and teacher, accompanied the group and along with the other program developers discussed topics and questions of interest to the visitors.

Perception Laboratory of Ohio State University

The Psychology Department of The Ohio State University maintains the Perception Laboratory and offers sessions featuring demonstrations and experiments related to man's visual perception of the world. These sessions are arranged for groups that represent diverse interests and backgrounds, including students at the University as well as "outside" groups. Sessions of two to three hours each were arranged for two conference tour groups with an emphasis on the educational implications of the demonstrations, experiments, and related discussion.

Interaction with an "Ames Room," a rotating trapezoidal window, rotating spiral, light "point" discrimination, and other phenomena provided experiences on which to base a discussion of the nature of perception and its influence in determing our transactions with many aspects of the world and universe.

One of the educational implications of the "perception" experiences is that understanding the concept of perception and its pervasiveness in all aspects of man's endeavors, represents a necessary factor in the development of scientific literacy in all humans. Another implication is that the pervasiveness of "perception" makes it an ideal unifying concept around which to organize learning activities from various natural, behavioral, and social sciences. And finally, the contribution of science to the understanding of perception and its application reflect the "practical" usefulness of science to man.

Academy for Contemporary Problems

This newly founded institution represents a unique cooperative effort by The Ohio State University and Battelle Memorial Institute. It is devoted to the serious and scientific consideration of contemporary social problems that transcend ordinary disciplinary boundaries. The Academy has a relatively small permanent staff but has provisions for maintaining visiting academicians for periods of a few weeks to a few months so they may give intense thought to a particular problem under consideration and interact with others from diverse backgrounds.

Many of the problems selected for study involve extrapolation from present conditions to those of the foreseeable future. Other problems attempt to construct scenarios that are the logical consequence of alternative decisions being made in the present or immediate future.

One of the particular problems into which the visiting FUSE Conference participants were able to gain insights was dealing with the future development of the city of Columbus, especially those geographical sections that represent older times and which presently are commonly regarded as less than desirable.

Center for Unified Science Education and ERIC for Science, Mathematics, and Environmental Education

Recent establishment of the FUSE Center for Unified Science Education at Columbus and its close working relationship with the Educational Resources Information Center (ERIC) were prime factors in the selection of Columbus as the site of the 1974 FUSE Conference.

The tour of the FUSE Center focused on its resources and program activities being developed and conducted under an enabling grant from the National Science Foundation and with additional support from the Ohio State University. The tour of ERIC emphasized its functions and resources, especially as they relate to unified science education. It was thought that a "first-hand" examination of the resources and personal interaction with staff members from each Center would enable participants to develop a reasonable familiarity with the resources and ways to facilitate their use. Three two-hour tours were conducted during the conference.

The tour groups, consisting of persons from elementary school level through college, were introduced to a number of specific resources designed to define and explicate the concept of unified science education and to assist local groups in developing their own unified science programs. These resources include a set of descriptions of unified science programs functioning throughout the country and the rest of the world, research and evaluative studies related to unified science, sample unified science instructional materials, and a variety of "workshop modules." The latter include "canned" presentations of unified science program case histories, role plan simulations designed to help groups consider the pros and cons of unified science, "live" presentation and discussion of teacher education strategies in unified science, etc.

Both the Center and ERIC were found to be open for direct use by working visitors and for remote use by persons unable to visit because of distance and time restrictions. Participants learned that many of the resources identified in the preceeding paragraph can be borrowed by mail for limited time periods. Suggestions for using these resources are made by the Center in accordance with the objectives of the user.

Workshop in Modular Unit Techniques for Unified Science

The purpose of this workshop was to enable the participants to gain insights into one method of implementing unified science in a real school situation. It was conducted by staff members of the Center for Unified Science Education.

The opening block of time was devoted to discussion of the rationale and philosophy on which unified science is based. A formal presentation was followed by questions and responses by various staff members of the Center.

The second block of time concentrated on an explanation of the modular unit format. Various illustrations and examples were used to show how each unit is composed of one introductory module (activity), one generalizing module, and several alternative modules. Criteria for assessing the quality of these units were discussed. Several typical locally developed units were evaluated in terms of these criteria.

The third block of time enabled the participants to become involved in the mechanics of designing unified science modular units in small teams. Each team designed a unit through an outline stage. Especially crucial techniques in the process were identified by members of Center staff. A number of valuable resources useful to and available to school science staffs were also identified and examples were on hand for participants to inspect.

The workshop closed after Center resources available to school personnel were described.

CONDENSED CONFERENCE AGENDA

	Morning	Afternoon	Evening
THURSDAY	WORKSHOP - Modular Unit Techniques for Unified Science (9:00-3:30)	TOUR - FUSE Center and ERIC (4:00-6:00) PANEL - University School Graduates (4:00-6:00)	GENERAL SESSION Prof. Philip Phenix "Theoretical Foundations for Unified Science" (8:00-10:00)
FRIDAY	TOUR - Villa Angela Academy (7:30-4:00) TOUR - Academy for Contemporary Problems (9:00-11:00)	TOUR - Perception Lab (1:00-3:00) TOUR - FUSE Center and ERIC (1:30-3:30) CONTRIBUTED PAPERS (4:00-5:30)	BANQUET Dr. Ralph Siu "Science and Contemporary Problems" (6:30-9:30) Cash Bar (6:00-6:30)
SATURDAY	CONCURRENT PANELS - Concepts in Science (9:00-10:20) CONCURRENT PANELS - Problems of Unified Science Education (10:30-11:50)	LUNCHEON SPEAKER Dr. Erwin Segal "Understanding the World" (12:00-2:00) CONCURRENT PANELS - Problems of Unified Science Education (2:00-3:20) GENERAL SESSION Dr. Victor Showalter "Unified Science Education Today and Tomorrow" (3:30-4:15)	INFORMAL DISCUSSION "Unified Science Education" (8:00-10:00)
SUNDAY	TOUR - Southcentral Ohio Natural Areas (8:00-3:00)		

Eighth Annual FUSE Conference

Participant List

Anderson, Dr. Larry - Ohio State University
Arnold, Howard - Columbus, Ohio
Awuku, Kwabena - SUNY, Albany
Bailey, Ouida L. - Sudbury, Massachusetts
Ballard, John - Galloway, Ohio

Beach, Dr. Darrell H. - Culver Military Academy
Binder, Dr. L. O. - National Science Foundation
Bok, Myron - Defiance, Ohio
Brito, Dr. Dagobert - Ohio State University
Broering, Sister Mary Ann - Melbourne, Kentucky

Champagne, Sister Ann - Flint, Michigan
Coleman, Davenport - Chicago, Illinois
Collins, Dr. William - Ohio State University
Coon, Dr. Herbert - Ohio State University
Coover, William - Upper Arlington, Ohio

Cox, David - Center for Unified Science Education
Craig, Jon - Chalmette, Louisiana
Cummings, Geoffrey - Columbus, Ohio
Dancey, Dr. William - Ohio State University
Davis, Dr. DeWitt - Ohio State University

Day, Dr. Gary - Cleveland, Ohio
Delaney, J. R. - Wayzata, Minnesota
Earl, Dennis W. - Columbus, Ohio
Easter, Thomas W. - Newark, Ohio
Enright, Karen - Chicago, Illinois

Fahner, Betty - Cambridge, Ohio
Feer, Michael - Sudbury, Massachusetts
Fiasca, Dr. Michael - Portland State University
Fletcher, Judy - Galloway, Ohio
Fretheim, Lee - Wayzata, Minnesota

Gabel, Larry - Columbus, Ohio
Gadsden, Dr. Thomas - University of Florida
Gonzalez, Juan Americo - Ciudad Universitaria, Mexico City
Graham, Carol - Chicago, Illinois
Guerra, Claudio - Ciudad Universitaria, Mexico City

Hanke, Russell J. - Wayzata, Minnesota
Hatfield, Dean - Bakersfield, California
Helgeson, Dr. Stanley - Ohio State University
Hennen, Dr. Ralph - Ohio State University
Holobinko, Paul - Center for Unified Science Education

Hord, Philip W. - Upper Arlington, Ohio
Howe, Dr. Robert W. - Ohio State University
Howland, Dr. Daniel - Ohio State University
Jednaszewski, Tom - Canton, Ohio
Kaiser, David - Canton, Ohio

Killius, David - Youngstown, Ohio
King, Dr. Charles - Ohio Biological Survey
Koch, Harry H. - Green Valley, Illinois
Liao, Dr. Thomas T. - SUNY, Stony Brook
Lillich, Dr. Robert - Denison University

Llamas, Dr. Vicente J. - New Mexico Highlands University
Mayer, Dr. Victor J. - Ohio State University
Melvin, Dr. Ruth - Ohio Academy of Science
Miller, Bernard - Ohio Department of Education
Montag, Betty Jo - Los Gatos, California

Mutzfeld, Harley R. - Lexington, Massachusetts
Nelson, Gary - Wayzata, Minnesota
Oriedo, Mika - Ohio State University
Owen, Dr. Dean - Ohio State University
Pegler, Don - Cleveland, Ohio

Pfeiffer, Carl H. - Monona, Wisconsin
Phelps, Margaret - Memphis, Tennessee
Phenix, Dr. Philip - Columbia University
Powell, Dr. Moseley - Memphis State University
Rentschler, Robert - Lansing, Michigan

Rheinfrank, Dr. John - Ohio State University
Richmond, James - Columbus, Ohio
Riley, Margaret - Louisville, Kentucky
Robinson, Dan L. - Bakersfield, California
Rohrer, William - Canton, Ohio

Santille, Roger - Westerville, Ohio
Saunders, Cynthia Mote - Westerville, Ohio
Segal, Dr. Erwin - SUNY, Buffalo
Sell, Paul W. - Canton, Ohio
Showalter, Dr. Victor - Center for Unified Science Education

Siu, Dr. Ralph - Washington, D. C.
Slettebak, Dr. Arne - Ohio State University
Smith, Jean G. - Orland Park, Illinois
Stano, Sister Diana - Cleveland, Ohio
Steiner, Dr. Robert - Ohio State University

Supinski, Richard - Pennsylvania State University
Suter, Robert - Bluffton College
Swami, Piyush - Columbus, Ohio
Sweitzer, Gary L. - Upper Arlington, Ohio
Syswerda, Ivan - Lansing, Michigan

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Taylor, Dr. Charles - Academy for Contemporary Problems
Thompson, Kenneth - Columbus, Ohio
Thomson, Dr. Barbara - Center for Unified Science Education
Thorson, Dr. Stuart - Ohio State University
Troyer, Robert D. - Owens Technical College
Turner, Frank - Canton, Ohio
Van Deventer - Dr. William - Western Michigan University
Verhoek, Dr. Frank - Ohio State University
Weaver, Richard - Bluffton College
Wilders, Richard - Columbus, Ohio

Wilson, Tom - Canton, Ohio
Wood, Dr. Donald - Ohio State University
Yarletts, Thomas G. - Columbus, Ohio