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ABSTRACT

The 1982 Search for Excellence in Science Education project has identified 10 science programs as exemplars in the teaching of science as inquiry. Descriptions of the programs and the criteria used in their selection are presented. Chapter 1 reviews four goal clusters (developed during Project Synthesis) related to the desired state in science as inquiry. These goal clusters, which focus on personal needs, societal issues, fundamental knowledge, and careers, were used as the criteria for defining excellence in these programs. Chapters 2 to 11 provide descriptions of the exemplary programs. The descriptions include: (1) information about the setting of the program (community location, size, specific features); (2) nature of the program (grade, level, class sizes, curriculum outline, learning activities, evaluation techniques); (3) origin of the program; and (4) what factors contribute to the program's success and what is needed to keep it going. Chapter 12 presents some generalizations and recommendations, indicating that these programs involve several years of development, are still evolving, do not place textbooks in a central position, have close ties with post-secondary education, and involve a locally developed curriculum. In addition, the teacher is the critical factor in designing and creating an environment conducive to inquiry. (JN)

FOCUS ON EXCELLENCE

SCIENCE AS INQUIRY

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PROLOGUE: EXCELLENCE AND THE SEARCH

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Many descriptions of excellent ideas, activities, and science programs have been published, read, and reviewed; resulting in considerable improvement in science teaching and additional recognition of continuing problems. With this beginning of the **Focus on Excellence** monograph series, The National Science Teachers Association hopes to provide a source of inspiration and ideas as well as descriptions of innovative and successful practices.

For 1982, our search has been for outstanding programs in five focus areas: Biology, Elementary Science, Science as Inquiry, Physical Science, and Science/Technology society. For each area, we are devoting a Monograph describing innovative programs with a particular focus. This continuing monograph series from NSTA will highlight excellence in Middle school/Junior High Science, Physics, and Informal Science Education in 1983. Future years will see a search for excellence in other school science, teacher education programs, and other science areas found in Science education. We feel strongly that this monograph series, **Focus on Excellence,** will play a needed and vital role in shaping science education practices of the future.

The 1982 Search For Excellence in Science Education began when Robert Yager, NSTA president for 1982-83, was invited to become a member of Project Synthesis. The perceived need for Project Synthesis came in 1976 when several National Science Foundation funded studies revealed the current state of science education in the United States. Then, in 1978, a synthesis of the more than 2,000 pages of information from those three NSF reports and the National Assessment of Education Progress data was begun by twenty-three science educators throughout the U.S.

The Synthesis researchers worked independently in small teams, each focusing on one aspect of science education: Elementary Science, Biology, Physical Science, Science/Technology/ Society, or Inquiry. A critical part of the synthesis analysis was developing a description of an ideal or desired state for a focus area and then comparing the actual to the desired state. During the Search for Excellence, goals arising from the synthesis desired state for each of the five focus areas were used as criteria for defining excellence in a school science program.

Leading science educators (generally state science consultants) in each state were identified as chairs of committees to identify and nominate outstanding science programs in their respective states. Ultimately, nearly 165 state nominations were submitted to the project director for consideration at the national level for 1982. Thus, the state exemplars were passed on to another set of review committees and yet another selection process.

To aid in the selection process, all nominees were asked to fill out forms detailing information on demographics, texts used, and the nature of the school. A questionnaire, developed from the desired state criteria, was completed by the nominee as an integral part of the nomination packet. In addition, the state nominees were given the major criteria for excellence and five questions to provide narrative information about their programs. These questions were:

1. Provide some information about the setting (community location, size, specific features, school science and organization)

2. Describe the nature of the exemplary program (grade, level, class sizes, curriculum outline, learning activities, evaluation techniques)

3. How does the program exemplify the 1982 criteria for SESE? (Abbreviated criteria were made availale and reference to Volume 3 of NSTA's **What Research Says to the Science Teacher** was given.)

4. How did the exemplary program come into existence?

5. What factors contribute to the success of the program and what is needed to keep it going?

Nominations were divided into five groups: Biology, Physical Science, Science/Technology/Society, Inquiry, and Elementary Science. Each group was then reviewed by different teams with at least one of the original synthesis researchers on each team. Each program was compared to the desired State criteria and reviewed by at least four independent reviewers with reviewer discussion usually leading to a clear identification of the national exemplars in each focus area. These National Exemplars numbered twelve in Elementary Science, seven in Physical Science, and ten each in Biology, Science/ Technology/Society, and Inquiry. A separate monograph for each focus area is available from NSTA.

While Project Synthesis offered a desired state, these examples of excellence provide vivid views of what is already a reality. We hope you can profit by reading these descriptions, by finding inspiration and a source of ideas. The programs described range from **North Toole High School** with only 80 students to **Merritt Island High School**, one of 23 secondary schools in the Brevard, Florida school district offering Research

Science. Schools with exemplary programs teaching Science As Inquiry are found in communities of 400 up to more than 50,000. Size of school or community does not seem to be a limiting factor in achieving excellence.

Grade level is not a factor either. Three of this year's exemplars are junior high schools and one program, **Inquisitive Chicks** is evolving in a primary setting. Not surprisingly, the most significant factor is the teacher. Teachers in all of these programs are dynamic, thoughful, young at heart, and eager to learn with their students. (If you are interested, see another monograph from NSTA, **Teachers in Exemplary Programs: How Do They Compare?**)

These programs are all exemplary but they by no means exhaust the supply of innovative and outstanding science education programs. We feel strongly that excellence exists and it exists in reasonable quantity. View these as **some** examples of excellence and be prepared to find more. At the same time, we encourage you to contact exemplary programs which you feel have applicability to your own school situation.

Chapter 1: Science As Inquiry:

A Desired State

By

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INTRODUCTION

Inquiry is a general process by which we seek information or understanding. People inquire in different identifiable ways and broadly speaking, it is a way of thought. We can inquiry into values (values clarification), natural phenomena (scientific inquiry), the application of techniques and knowledge (problem solving), and into choices of action or belief (decision making). Thus, scientific inquiry belongs to a family of inquiry strategies. While scientific inquiry shares common features with the other modes of inquiry, it may be characterized by its own set of features. Our Project Synthesis inquiry group recognized scientific inquiry as having:

1. Specific characteristics such as the processes and methods of science: observing and measuring; formulating problems and seeking solutions to them; interpreting data; generalizing, building, testing, and revising theoretical models.

2. General characteristics often called the nature of science: the structure of scientific knowledge is tentative and the product of human efforts. The structure is affected by the processes used in its construction or by the social and psychological context in which the inquiry occurs. Scientific knowledge is also affected by assumptions about the natural world, such as causality, noncapriciousness and intelligibility.

*These Desired state ideas were developed as part of Project synthesis. Contributing authors and members of the Inquiry Focus Group also included: Wayne W. Welch (University of Minnesota, Leo E. Klopfer (University of Pittsburg), and James T. Robinson (Boulder Valley School District, Boulder, Colorado). This chapter is based in part on Chapter V in N. Harms and R. Yager (Eds.), *What Research Says to the Science Teacher*, Vol. 3, NSTA, Washington, D.C., 1981.

3. Shared characteristics with other domains of inquiry such as general strategies, safeguards and customs: the use of evidence and reasoning, and the generally agreed-upon procedures of "ethos" that individuals participating in all forms of rational inquiry are expected to follow. Our characterization of scientific inquiry encompassed these three themes. A more detailed description may be found in Table 2.

A desired state of affairs for student understanding and use of inquiry requires more than a definition of inquiry. We deliberated over issues related to schooling and considered the needs and characteristics of students. In order to analyze these school issues we developed three main themes: the context or precondition that may support inquiry teaching, the transactions that may facilitate inquiry teaching, and the outcomes of that instruction--student understanding of inquiry. These outcomes were considered in terms of Project Synthesis' student goal clusters:

I	Personal Needs	-- to use the outcomes of science instruction for improving one's personal life and for coping with an increasingly technoligical world,
II	Societal Issues	-- to use the outcomes of science instruction to deal responsibility with science-related societal issues,
III	Fundamental Knowledge	-- to use the outcomes of science instruction for the pursuit of knowledge for its own sake and for professional training, and
IV	Careers	-- to use the outcomes of science instruction for awareness of a variety of science and technology-related jobs.

Table 2 shows interrelationships among the three inquiry themes, the three themes for school issues, and the four goal clusters. The goal clusters and the inquiry themes form a two dimensional lattice, and are related to only one theme of the school issues--outcomes.

In formulating desired states for teaching science as inquiry, we were mindful that our assumptions, experiences, and beliefs were influencing the outcomes of our deliberations. The validity of our desired states must be considered in this light and before presenting the desired states themselves, you should note their inherent assumptions, beliefs and restrictions.

ASSUMPTIONS, BELIEFS AND RESTRICTIONS

There were several assumptions, beliefs, and restrictions that guided the Inquiry group's interpretation of the inquiry domain.

1. Inquiry as a way of thought is a valuable goal for education.

2. There are certain characterisitcs of the nature of scientific inquiry that students ought to learn.

3. Scientific inquiry is not a prescribed set of steps, but it does contain some common elements that need to be addressed.

4. Process is pervasive. It, together with conceptual schemes, will likely remain after the content is forgotten.

5. We recognize and advocate the importance of informed attitudes as an integral part of scientific inquiry. Students will possess informed attitudes toward the process of discipIined inquiry, particularly processes and knowledge characteristic of scientific inquiry. Indications of the existence of such attitude will span the continuum from merely being aware of phenomenon (receiving) to making a concerted effort to respond (organization). For some students, attitudes toward scientific inquiry will become their life outlook (characterization). Students will exhibit different feelings about different components of the processes of science, but our desire is that students will respond to the process of science with positive feelings (valuing). In our statements of desired student outcomes we have chosen to weave affective (feeling) statements in with our cognitive (knowing) and skill (doing) statements.

6. We recognize that all possible desired student elements could not be covered in a document such as this. Therefore, we have sampled the domain of inquiry selecting those aspects that are most important and presented examples of these across the four goal clusters.

7. The student outcomes are pitched at the able high school graduate, but we expect a range of competencies.

8. Our description of a desired state of affairs for inquiry is based in part on earlier writings of Klopfer. (1976) (Inquiry Report, October 21, 1978, pages 1 and 2)

DESIRED STATES FOR INQUIRY

The desired state of affairs for student understanding of Science as inquiry involves all the elements found in Table 2. A physics metaphor may make evident the context, transactions and outcomes sections below. A physical system has a potential for doing work (the context), but must develop the kinetic energy for that work (the transactions), and finally the system yields the work itself (the outcome).

The contextual component includes such things as curriculum materials, skilled teachers, science laboratories and community opinion. Context is the potential of the system to accomplish inquiry learning. A school that contains a well-equippped science laboratory, a highly competent teacher and a supportive community has a greater potential to accomplish inquiry learning than one which does not. Whether or not this potential is realized depends, in part, on the classroom transactions.

The teacher is the critical factor in achieving a desired state consistent with inquiry teaching. Effective teachers value inquiry, encourage an inquiry orientation in others, and possess skills in enabling other to understand inquiry as a way of knowing. Such teachers take advantage of investigations to develop an understanding of the history, philosophy and sociology of science, and to develop their competencies in inquiry teaching.

Inquiry classrooms have science objects that are obviously in use with equipment and supplies organized and available in such ways as to stimulate student investigations. The physical arrangement of the classroom is flexible, permitting activities of various kinds without undue problems or loss of time.

Curricula include explicit statements of desired student outcomes that give attention to science process skills, to the nature of scientific inquiry, and to attitudes and values. Science curricula that incorporate these outcomes are available to all students, but statements of student outcomes and instruction should be carefully adjusted to the characteristics of the student population, including their needs and goals.

Transactions are the set of activities that expose the student to opportunities to learn. They are the actual interactions of the students with their teachers, other students, curriculum materials, and the natural world. There is a kinetic characteristic of the transactions that distinguishes them from the context elements. Participating in hands-on experiences, viewing a film on the double-helix controversy, or reading about the philosophy or sociology of science are examples of transactions that would seem to facilitate inquiry learning in science.

Instruction in inquiry classrooms reflects a variety of methods--discussions, investigative laboratories, student-initiated inquiries, and debates. Teachers serve as role models in debating issues, examining values, admitting error, and confronting areas of their own ignorance. The classroom atmosphere is conducive to inquiry with students finding it easy to ask questions. Risk-taking is encouraged and stuudent comments are listened to, clarified, questioned, and deliberated with a high level of student-student interactions. Science content and processes become inseparable and "How do we know?" enters many conversations. Individuals, small groups, or the entire class move easily from discussion to laboratory or other "hands-on" activities. The climate of classrooms in which science is taught as inquiry stimulates a thorough, thoughtful exploration of objects and events, rather than a need to finish an activity or the text.

Both formative and summative evaluations are integrated into the ongoing activities in the classroom. Techniques and instruments for summative evaluation are selected and used in such a way that student outcomes reflecting inquiry learning are assessed. With equal importance, formative evaluation procedures and instruments are deliberately chosen to gather data for course improvements and future directions and decision making.

Inquiry transactions are concerned with students developing meaning for themselves. The multifarious nature of such meaning dictates that in an inquiry classroom there is a time for doing, a time for reflection, a time for feeling, and a time for assessment.

Outcomes of the schooling process are the result of transactions occurring in a particular context. A student's awareness of the tentative nature of scientific knowledge is one example of an inquiry outcome. A student's ability to interpret data represented in a graph is yet another example.

When we developed student outcome statements, it was obvious that only sample statements could be generated within a reasonable time-frame. These statements, 128 in all, serve to exemplify the three main themes of inquiry and the four goal clusters. Table 3 presents a few of the 128 examples of desired inquiry outcomes generated by the Project Synthesis Team (Harms, 1980).

A PERSONAL DESCRIPTIVE ACCOUNT

The Inquiry group's story begins with Norris Harms' decision to include "Processes of Science" as one of the five focus groups in Project Synthesis. Consequently he needed a group leader, a person who had gained a national reputation in research and study of the processes of science. Wayne Welch's name came quickly to mind. Welch's doctoral work (1966) at the University of Wisconsin had created the widely used <u>Science Process Inventory</u> (SPI). Welch also was working on a National Assessment of Educational Progress study involving the processes of science when Harms was writing the Project Synthesis proposal for NSF. In addition, he had been involved in all three NSF supported studies that were to form the empirical basis for Project Synthesis. Welch's academic background, diverse research, and administrative experiences were seen as beneficial in developing and heading up the Processes of Science focus group.

When NSF funded Project Synthesis in the spring of 1978, Welch's first task was to select three others to work with him. The selection criteria in the original NSF proposal dictated a literature search to discover who had done research related to the processes of science. In consultation with Harms and other members of the steering committee, Welch also attempted to predetermine the compatibility of the group, estimating how well the people would work together on an extensive, nebulous and taxing project.

Three people were selected: Leo Klopfer (University of Pittsburgh), Jim Robinson (BSCS), and Glen Aikenhead (University of Saskatchewan). Leo Klopfer's <u>History of Science Cases</u> plus his <u>Test on Understanding Science</u> (TOUS) were all part of his doctoral research at Harvard University. (1962) His Chapter, "Evaluation of Learning in Science," in Bloom et al.'s classic <u>Handbook on Formative and</u>

Summative Evaluation of Student Learning (1971) reflected a national recognition of his expertise. Jim Robinson's philosophy of science doctoral thesis at Stanford (1964) had led to his book The Nature of Science and Science Teaching (1964). My doctoral work at Harvard University (1972) continued the development of evaluation techniques using the SPI and TOUS and led to subsequent research studies evaluating student knowledge about science and scientists.

Welch and Harms felt that the four constituted a potentially compatible, valid array of academic researchers. What Harms may not have known at the time was that we each had personally become involved in the practitioner's world of teaching. Welch had worked closely with Harvard Project Physics teachers, Klopfer in Individualized Science trial classrooms, Robinson with BSCS materials in trial classrooms (Life Science for Educable Handicapped, Environmental Education Project, Human Sciences), and I with my own project, Science: A Way of Knowing, for which I had returned to high school teaching over a two year period. Thus the four of us brought a wealth of practical knowledge of the day-to-day limitations and frustrations experienced by and imposed on classroom teachers. We knew from personal experience what might or might not be accomplished in a classroom with different sorts of students. We had a pragmatic feeling for what is reasonable to expect of teachers in various circumstances. This practical knowledge, rather than just academic expertise, turned out to be the basis for formulating much of the desired state for inquiry.

In spite of this academic background and personal experience, we certainly could not pretend to have a monopoly on the desired state of affairs related to the processes of science. Our deliberations had to be more broadly based in order to secure a valid conclusion. Consequently, before our first meeting in Boulder (June 1978), we studied at least 20 major articles that addressed ideas about what should be taught in science classroom. These articles were scrutinized and discussed in terms of what they justified as a desired state of affairs.

Our initial task was conceptualizing what the processes of science meant in terms of Project Synthesis. Harms' broadly encompassing viewpoint seemed at first unwieldly but, as soon as we realized that we were dealing with a subset of inquiry, a pattern emerged, inquiry as a way of thought, scientific inquiry as a way of generating knowledge, and scientific inquiry as a repertoire of intellectural skills. With this realization, we changed the focus group's name from "Processes of Science" to "Inquiry."

These three themes were broken down into subthemes (Table 1) and each of us took the task of writing illustrative student outcome statements. We wanted to express the desired state of inquiry instruction with a sample of specific student outcomes. Three types of statements were called for: knowledge of (at various levels on Bloom's taxonomy), ability to do, and feeling about. We wrestled with many problems, such as the illegitimacy of isolating inquiry from science content (recognizing that the two are intimately related), the realism of some student inabilities and apathy, the incompleteness of any set of outcomes we might generate, and the bothersome issue of elitism.

Deliberations over student outcomes allowed us to deal efficiently with what eventually became our "context" and "transactions" segments. Our own experiences with teaching and working closely with teachers helped us reach agreement over a desired context and a desired set of transactions.

The intensity of our deliberations may be compared to a three-day comprehensive examination both oral and written. One incident exemplifies this exciting tension. We drove to a restaurant one evening while carrying on a discussion from our afternoon meeting. When we jumped out of the car and crossed the street, Harms noticed that Klopfer was not with us; that he was sitting pensively engrossed in the back seat of the car. "Leave him alone," someone advised, "he's thinking." Twenty minutes later he entered the restaurant with a trace of a smile on his face. He had gotten hold of an idea, but we would have to wait for him to think it through overnight before he was ready to share it with us over breakfast in the morning.

TABLE 1

Interrelationships Among the Desired States for Inquiry Instruction

A. Context: the community, teacher, classroom and curriculum

B. Transactions: the classroom events, methods, atmosphere and evaluation

C. Outcomes:

	I	II	III	IV
	Personal Needs	Societal Needs	Fundamental Knowledge	Career
1. Processes & Methods of Science				
2. Nature of science				
3. Strategies, Safeguards & Customs of Inquiry				

Table 2

Domain of Inquiry: Themes and Subthemes

I. Processes or Methods of Science
  A. Observing and Measuring
  B. Seeing a Problem and Seeking Solutions

  This process refers to that rather difficult task of recognizing or choosing problems and then through a combination of hard work, thought, skill, past experience, or just plain luck, finding solutions to that problem. Also involved are such things as problem recognition and developing and testing hypotheses, often through experiments.
  C. Interpret Data and Form Generalizations
  D. Building, Testing, and Revising a Theoretical Model

  Theoretical models are viewed as conceptual schemes that allow us to understand a variety of phenomena in the natural world. Good models are broadly generalizable and can be used to generate predicitions to be tested. They indicate how observations and concepts are related.

II. Nature of Scientific Inquiry
  E. Scientific Knowledge as a Product of Scientific Inquiry

  Scientific knowledge consists of ideas about natural phenomena in the form of: observations, laws, hypotheses, theories, models, and assumptions. This knowledge is tentative. It is the product of human effort. Scientific knowledge and the direction of inquiry itself are affected by a number of psychological and sociological influences, such as the social context in which the scientific inquiry occurs. Scientific knowledge comprises the assumptions and metaphors of those who created it, those whose principal aim was to satisfy their curiosity about natural phenomena. Thus, there are limitations to scientific knowledge and scientific inquiry; limitations related to psychological and sociological effects and limitations possibly bounded within the domain of natural phenomena. There are some basic assumptions in scientific inquiry which have endured over a long period of time. These assumptions about the natural world include: causality, noncapriciousness, intelligibility.

F. The Diversity of Tactics and Strategies in Scientific Inquiry

While different branches of science share similar types of inquiry, there are as many different "scientific methods" as there are scientists. However, two modes of inquiry are often recognizable: (a) stable inquiry--inquiry proceeding within the theoretical structure of the discipline, without challenging the accepted scientific knowledge of that area; (b) fluid inquiry--inquiry that challenges, and perhaps alters, the theoretical structure of the discipline.

G. The Self-testing and Empirical Aspects of Scientific Inquiry

Scientific knowledge raises questions about phenomena. In an attempt to answer these questions, scientists create hypotheses. Scientists test these hypotheses by means of independent empirical verification (observations are gathered by different people under experimental conditions, and then these observations are compared with predictions deduced from the original hypothesis). The observations used to verify or falsify the hypothesis are: (a) contingent upon the experimental conditions and the instruments used to gather the data, and (b) judged true if they are based on sense data, repeatable by anyone trained in inquiry techniques.

Theories are useful ("true") to the extent to which scientists believe in the confirming observations. Criteria for accepting a theory include such things as logical coherence, simplicity, explanatory power, predictive power, potential for growth in developing scientific knowledge. Theories guide observations. Disconfirming observations may lead to: modification, restriction in the scope of application, or replacement of the theory.

Scientists publish their results so that: others can repeat what they did, critically analyze the work and know who should receive credit for a new idea.

III. Inquiry As A Way Of Thought

H. Strategies of Inquiry

1. Is it a values or values-related question? If yes, use values-clarification strategies.

   Is the aim to develop scientific knowledge and understanding? If yes, use strategies detailed in "Processes of Scientific Inquiry."

Is the purpose (need) to apply knowledge, skills, and/or procedures to a personal or engineering-type problem? If yes, use general problem-solving strategies.

Is the purpose (need) to decide on alternative societal actions to be taken? If yes, use decision-making stategies.

NOTE: Which ever set of strategies is selected, all the considerations discussed under Evidence, Reasoning, Safeguards and Customs apply.

2. Evidence

Includes questions of relevance, usefulness, judging reliability, and utilizing evidence to make decisions.

3. Reasoning--use of logical thinking. Includes logical reasoning, analogical reasoning, assumptions, causality and multiple-causality, judging alternatives.

NOTE: Consideration also must be given here to alternative systems of logic--especially the logic systems of children (and adults?) who have not attained the stage of intellectual development often described as the Piagetian formal operations stage.

IV. Safeguards and Customs of Inquiry

These are the generally agreed-upon procedures, operating modes, rules of the game (the "ethos") that individuals participating in all forms of rational inquiry are expected to follow. Some of the more important procedures include open-mindedness; criticalness, including one's self; commitment to accuracy; integrity; and sharing through public discussion, seminars, and written reports.

TABLE 3

A Sampling of Desired Student Outcomes**

(A * indicates a minimal outcome. Other statements refer to students taking two or more science classes in high school)

GOAL CLUSTER I Personal Needs	GOAL CLUSTER II Societal Issues
A. *(Doing). Can measure accurately those body symptoms, such as blood pressure, heartbeat and temperature, that are important in monitoring one's health	A. *(Doing). Observes the impact of his/her actions on the rest of society, both those that are negative (noise pollution); and those that are positive (not smoking in a crowded room).
B. *(Knowing). Is able to form and test hypotheses around problems related to personal needs and interests, such as acne, overweight, low grades, autos that won't start, and water in the basement.	B. (Attitude). Are supportive of the allocation of public funds for use in solving the science-related problems of society.
C. *(Doing). Can judge the appropriateness of any hypothesis tested, to solve a personal problem, on the basis of data obtained, such as cost of gasoline and mileage rates.	C. (Doing). Can interpret data presented about a societal problem and judge its implications for personal behavior the effect of limiting speeds to 55 mph and resulting gas usage.
D. (Attitudes). Realize that the possession of a few broadly encompassing models will help them interpret and feel better about their environment. Examples include justice/fairness, socio-biology, evolution, compromise, and democracy.	D. (Knowing). Several models are proposed accounting for social behavior. Insofar as these are adequate, it seems important that students are familiar with them. Some examples include justice/fairness, socio-biology, evolution, compromise and democracy.
E. *(Knowing). Deliberately recognizes that the relevance of scientific knowledge is likely limited to its own domain of inquiry (natural	E. (Doing). Abstracts from a societal issue the component related to natural phenomena, identifying this component as being ger-

phenomena) and that other personal inquiries about one's life may not use scientific knowledge or scientific inquiry.

F. *(Knowing). Does NOT have faith in following a stepwise description of "the scientific method" as a way to solve problems.

G. *(Attitude). When engaged in scientific inquiry, values the empirical verification basis of science.

H. *(Doing). Studies the research report containing new evidence concerning the connection between smoking and lung cancer to find out the conditions under which the study was carried out.

I. *(Knowing). Accepts open-mindedness as a prerequisite to successful inquiry.

mane to scientific knowledge and scientific inquiry.

F. (Attitude). Accepts or anticipates that the science component of a societal issue can give rise to different solutions.

G. (Attitude). Does not expect scientitsts to use knowledge in their scientific thinking unless it has been verified empirically by independent groups.

H. (Attitude) Has faith in the power of reason and in systemic approaches to problem-solving for science-related social problems.

I. (Attitude). Consistently insists on giving opportunities to be heard to proponents of various viewpoints concerning water and air pollution issues.

GOAL CLUSTER III
Fundamental Knowledge

GOAL CLUSTER IV
Careers

Science Process Skills

A. *(Doing). Is able to observe and describe objects and phenomena (including change) using appropriate language.

B. *(Knowing). Recognizes that problem selection and hypothesis formation are sometimes accomplished in direct and programmed ways and other times it is very

A. *(Doing). Participates in a variety of observational and measurement activities to sufficiently examine the potential and interest to them for a career in science.

B. *(Attitude). Enjoy involvement in opportunities to participate in science-related problem identification and solutions.

much an unpredictable affair. In both cases, however, it involves intelligence and patient, hard work, though neither guarantees success.

C. *(Attitude). See value in presenting data in the form of functional relationships, such as tables, graphs, equations.

D. (Knowing). Can specify which phenomena and principles are included in a model.

E.*(Doing). Cities example of earlier and current scientific explanations which have been, or are being, altered.

F. *(Attitude). Expresses the view that different scientists may use different methods of inquiry because of individual differences among scientists.

G. *(Knowing). Acknowledges that scientists deal with hypotheses, theories and models in terms of their usefulness (in explaining, predicting and encouraging growth in science) and not in terms of their absolute truth.

H. *(Knowing). Can grasp the meaning of simple scientific statements such that he or she would know what counts as evidence for and against it.

I. (Doing). Accepts the disagreement of scientists

C. (Doing). Has experienced the successes and problems of interpreting data and forming generalizations to realistically consider careers in science.

D. *(Attitude). Appreciate the value of models in understanding natural phenomena and is interested in pursuing careers that use such approaches.

E. (Knowing). Recognizes the latitude in science for expressing human ingenuity and creativeness

F. (Knowing). Recognizes that a career in science does not require a singular role, but is open to a number of different roles.

G. (Empty set)

H. *(Doing). Decides what the main issues of selecting a science career are.

I. (Doing). Values open-mindedness in

about interpretations of the outcomes of scientific research.	those who pursue scientific careers.

**The A, B, C . . . headings for the outcomes correspond to the sub-themes described in sections A, B, C . . . in Table 2.

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Chapter 2: THE RESEARCH SCIENCE PROGRAM: A PROGRAM FOR HIGH ABILITY STUDENTS

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Merritt Island, with a population of about forty thousand, is surrounded by water on three sides. The Kennedy Space Center, beaches, and mild climate are the main attractions of the Merritt Island area.

Prior to the development of the space program, Merritt Island was primarily a rural community of citrus growers although there was some tourism in the area. The early development of the space program at Kennedy Space Center and the adjacent Cape Canaveral Air Force Station brought many space related contractors and industries to the area. These new industries changed Merritt Island into a more cosmopolitan community with many diverse groups including citrus growers and pickers, technicians, engineers, and administrators. It was during this time of rapid growth and expansion that Merritt Island High School was constructed in 1965.

Although Merritt Island's population has not decreased appreciably in the last few years, the transfer of Mission Control from Kennedy Space Center to Houston reduced the input of young families in the area. This also decreased available jobs in space-related industries and altered as well as decreased the school population. Our community has become more retirement oriented and students no longer are automatically interested in pursuing a career in science.

Merritt Island High School, with six wings surrounding a commons area, provides educational opportunities for 1,545 students in the tenth, eleventh, and twelfth grades. The staff includes three administrators, two deans, five counselors, and eighty-five teachers.

The Science Department has eight teachers offering first and second level courses in Biology, Chemistry, and Physics, as well as electives in Marine Biology, Anatomy and Phsiology, and Research Science. The twelve math instructors teach a series of standard mathematics courses including Calculus. In recent years, the Science Department has been instrumental in the development of a computer math course at Merritt Island High School.

Students at Merritt Island take advantage of these science offerings with 91% taking biology, 42% Chemistry, and 27% Physics or Physical Science before graduation. Another 24% take Marine Science, 7% take anatomy and Physiology and 10% take a second year of Biology, Chemistry or Physics. Research Science attracts 9% of the students by the time they graduate.

Prior to development of the Research Science program, science courses at Merritt Island High School were laboratory oriented, with a hands-on approach used in conjunction with texts and AV and other materials. Inquiry was promoted in regular science classes but with all students in a particular class solving the same problems, usually as prescribed by a laboratory manual. Any individual inquiry was not directed or supervised by the teacher and, in many cases, not even encouraged. There was not enough time in the regular classroom to cover necessary material or to truly help students develop their talent in individual problem-solving techniques while accomplishing highly technical procedures.

For a number of years teachers were required to use a district adopted text and to observe district wide objectives in regular science classes. As long as the teacher met the objectives for the course, there was a great deal of freedom allowed in "how" to teach the course. This is still true today. With the large number of students interested in technical and scientific fields, we felt a program geared for the special education of these exceptional, gifted and creative students was needed. We wanted a program allowing students to proceed far beyond the best that the usual science curriculum could offer them, especially in the area of inquiry.

The philosophy of the program developed is that through participation in research, some students may in fact be able to develop more of their potential. The express purpose of the program is to develop sophisticated techniques for encouraging independent student investigation and teaching the skills and concepts for such independent research. It is intended to teach the students the careful, patient, exacting and creative methods of study and laboratory investigation used in inquiry by professional scientists. Students learn science through real personal research which might ultimately lead to publication. They practice scientific thinking and learn scientific processes which firmly establish and further advance the student toward career goals.

The science research program implemented at Merritt Island High School began with a series of five grants from the National Science Foundation. During this formative time and continuing through his retirement last year, Mr. Robert E. Bruton, our principal, inspired and supported the development of the program. He encouraged teachers, secured and channeled funds for equipment, and encouraged students to attend functions, even some distance from Merritt Island. He also helped establish rapport between the Research Science Program and the faculty as a whole. His contribution cannot be overestimated.

In the summer of 1968 two teachers, Patricia Denninghoff and C.D. Gimbel, took an NSF sponsored program to aid teachers in continuing district support of previously funded NSF programs. Mrs. Denninghoff served on a committee to acomplish this implementation of continuing support and to write the proposal for the organization of the Research Science Program as it is today. This was revised in 1975 and again in 1981. The same committee also produced the current Research Science Program guide for administrators, teachers, and students throughout the Brevard County School district.

The teachers at Merritt Island High School now consist of Patricia Denninghoff in biology and chemistry; Kenneth Marx, who also took a NSF training program, in physics and engineering; and Barbara Louden who has assisted for the last two years in the areas of mathematics and computers.

OUR FACILITIES

The Research Science Program functions in a setting which includes two research rooms, a sterile room, and an instrumentation room specifically for their use. The atmosphere and setting of these classes is conducive to the inquiry approach. The physical science research room, 7 meters by 8 meters, has lab tables and cabinets around the perimeter and a fume hood in one corner. The equipment present depends on which projects are set up at a given time and may range from lasers to pumps; from electronic equipment to fiber optics. The biology research room is 5 meters by 10 meters and includes a sterile room 2 meters by 3 meters enclosed in the main room. This sterile room is equipped with a laboratory table, sink and gas outlets. Present also are a carbon dioxide incubator, an inverted tissue culture microscope, a refrigerator, and various shelves. Germicidal ultraviolet fixtures are attached to walls above all work areas, and high efficiency filters purify both incoming and outgoing air.

The main biology research room also contains the usual science laboratory stations around the perimeter with a fume hood on one wall. Incubators, refrigerators, centrifuge, microtome, glove box, autoclave, and a Warburg apparatus are present also. Two racks of small animal cages and a number of individual rabbit cages remind you this is a biology room. The nearby science stockroom contains a library with technical, text books, and catalogues for use by research students. Outside, a fence encloses an area originally intended to be a laboratory and a place for a plant and animal house. This facility has never been built and the area is currently being used as a playground for the child care classes at Merritt Island High School.

In addition to the equipment already mentioned, the research program has a Spec-20 spectrophotometer, an infrared spectrophotometer, and a gas chromatograph. These, along with an excellent medical microscope, phase contrast microscope, the computer facility, the Warburg apparatus, and the tissue culture microscope are all essential to the success of various of the student's projects and probably would not be found in an ordinary science program.

The equipment in these rooms is available only to research students for independent study projects; non-research students do not use this equipment. As a result, those students involved in individual inquiry problems may leave their equipment set up as long as is necessary without fear of casual or deliberate destruction of the fruits of their labor.

A prep room adjacent to Mrs. Denninghoff's room serves as a computer room. It contains an Atari 800 computer, a monitor, disc drive, and daisy wheel printer. An electric typewriter, paper cutter, and other paper processing equipment also are found in this room to which students have access when Mrs. Denninghoff is in the building.

The research science rooms have space that is adaptable to the set-up of varied types of experiments. This laboratory space may "belong" to a particular student for the entire school year and even carry over for all three of the student's years at Merritt Island High School. In addition to the versatile science classrooms and special research rooms, including a sterile room built at Merritt Island High School using community and parent provided contributions and labor, portions of the program take place in NASA laboratories at Kennedy Space Center; and at the Florida Solar Energy Center, Medical Research Institute and Florida Institute of Technology, Brevard Community College, and the University of Central Florida.

Individual students also work in laboratories at various Summer Science Institutes, such as the program at the University of Florida, as well as in industrial labs such as at the Harris Corporation. In general these institutions have been well pleased with the quality of performance of research students. Many students have received summer employment, part-time school-year employment while at college, or while at college, have entered a co-op program with the institution which helped them while in high school.

Most materials and equipment are stored and available to students when one of the teachers is in the building. Mrs. Denninghoff is in the building two evenings per week for three hours each, on a regular basis, and extra hours are put in by Mr. Marx and Mrs. Denninghoff when necessary to provide access to materials and equipment needed to meet certain deadlines and competitions.

In addition to the daily Research Science class, teachers must be available to students for at least eight hours a week after school. Most Research Science Teachers put in more than is required.

OUR STUDENTS

Over the course of the years schools have recognized that only a relatively few students will excell in a given field. As a result, education in general has been geared toward the average student. The research Program at Merritt Island High School is designed primarily for the special education of exceptional, gifted and creative students in all grades from 10 through 12. It is also considered for the occasional academically under-achieving student who may become more involved in academics through an extreme interest in doing independent study in science. Physically handicapped students are enrolled in the program as long as they can meet the other qualifications. This year's Research science students include individuals from all socio-economic and ethnic groups found in the general population of the school.

Three related qualifications of students are: a willingness to spend time beyond ordinary assignments and make personal sacrifices to succeed in the program; perserverance and not becoming discouraged by failure, since experimentation often results in failures before success is achieved; and emotional maturity, insuring self discipline, cooperation, dependability and related traits.

Participation in the Research Program by the students of Merritt Island High School is expected to cause changes in their behavior in the cognitive, affective and psychomotor domains. The nature of many of the desired learning outcomes is such that complete and immediate evaluation of the program is impossible. The extent to which a student has acquired the complete problem-solving skills, manipulative skills, and positive attitudes which are the goals of this program may best be expressed in terms of long-range behavior, such as success in university level research or selection of a vocation.

GOALS AND METHODS OF RESEARCH SCIENCE

Through this program students are exposed to a wide range of scientific problems and possible solutions. They come in contact with evidence that discovery can change the future of the world. The entire program emphasizes this general idea through specific examples found in their own research. The Research Science program demonstrates that the inquiry approach to problem solving is an effective way to solve any kind of problem by finding as much information and evidence as possible. Students also learn that the accuracy and statistical analysis of evidence is critical in the solution and its defense.

Some projects deal with socially-related problems such as handicaps, drug use, effects of alcohol and nicotine, pollution, or other science-society issues. Each student's research is a unique situation, and through exposure to the projects of others, each student becomes aware of inquiry processes involved in many different scientific disciplines and intimately aware of those involved in his own specific project area.

Through project work and the inquiry approach students learn that valid decisions require an accumulation and classification of evidence. They look for and recognize accuracy in information. Since decision making in social contexts often involves bias, this emphasis on accuracy leading to valid decision making is invaluable. Research science students are intimately exposed to careers which relate to their projects. They meet and discuss problems with "experts" in their chosen fields. By actually performing experiments in the field and using the inquiry approach individually they learn, first hand, how and in what types of environments research scientists and technicians work. In some cases they learn that they do not particularly care for a certain career, but they may also find one in which they will feel accomplishment and pride.

Much of the inquiry approach used in student projects applies to science-related problems which have value and ethical and moral considerations. Some of these are safety and pollution problems and others are those in which scientific evidence can lead to better decision-making. They learn that honesty and accuracy in reporting data is essential for problem solving, and that this applies to non-scientific problem solving as well. Doing individual inquiry type projects leads to an awareness that science related problems often do have these kinds of considerations and prepares the student to better handle such decision making.

This program is almost entirely problem-centered and is flexible to the point that each student is allowed to pick his own problem as long as there is a reasonable probability of his success in its completion. Almost all projects in this program deal with a problem which will improve the quality of human life in some way while very few projects deal with "pure" science projects. The entire program is individualized and personalized by allowing the student to select his problem, and then helping and guiding him through the inquiry approach to solve that problem.

The projects are as diverse as the students and faculty involved. Independent study projects often deal with problems of the community. One tenth grader, after presenting his study at an EPA hearing to set policy for control of sewage into Sykes Creek, received letters stating that his scientific presentation was the most useful in helping them make their decision to curtail this discharge. This use of the natural environment occurs often in this program with Community resources such as industrial facilities and personnel, libraries, university laboratories, and professors, hospitals and doctors commonly involved. Often the students use each other, other students, adults, or whole schools as subjects.

Much of the problem solving that is done by students is of a social nature in that communication and salesmanship are necessary for success in getting assistance, both monetary and scientific. Students learn to make social contact by telephone, letter, and personal interview. An important aspect of the Research Science program is helping students learn how to communicate their ideas. English teachers provide critiques of science reports prior to competitions and students are videotaped during practice presentations. The students critique each other and also receive feedback from teachers. This feedback encourages students to be concerned with delivery and appearance as well as substance.

Cooperative work on problems exists in the form of advice given at seminars presented by each student. They frequently "tear each other apart" at these seminars and all learn thereby. Help is given also by students already expert in some field, such as electronics or computers, to those less expert in that field. The cooperative nature of the program leads teachers to believe that the development of the student as a person is more important than the specific techniques and body of knowledge which is learned. One can see the students develop into thinking, learning, involved young adults who can make decisions in all aspects of life and base them on information and evidence gathered using the inquiry approach to problem-solving. Since teachers are not "expert" in all the different projects being performed, they must assist students in problem-solving techniques rather than finding "the solution" to the problem.

Students have a class period each day in research under the guidance of a research teacher. In addition, a minimum of four hours per week is required for additional laboratory or research work with a time log required to show when and how this time is spent. Each student maintains notebooks and a file containing the time log, a hyothesis and problem statement, methods and procedures required in the research, a research plan, consultants' names and addresses, equipment used and needed in the future, and compiled data and results. Each student is required to bring these materials to a weekly evaluative conference with the teacher. Each is also expected to present his research to all others involved in the program in oral seminar form at least once during a six week period and a written report is required at the end of six to nine weeks.

Each researcher enters at least two of the various competitions available during the year, including regional science fair, Westinghouse Science Talent Search, Florida Junior Academy of Science, and various grant programs. During this time students are responsible for their own work as well as maintaining a clean and organized work area. At the end of the year, a final paper is required covering published background material in a specific area, the individual's own research data, data analysis, conclusion and a statement of unresolved problems and their significance.

Student project work is done in any field of science in which the teacher feels there is available equipment and expertise for successful completion of the research. In this program students play an important role in planning, clasroom management, and decision-making. Each student picks his own problem, within the limits of feasibility, and writes a research plan, carries out the experiment and comes to conclusions. Each student determines the validity of his results and uses data analysis to assist him in making these conclusions. All of this is performed using guidelines, deadlines and teachers suggestions, but remains his own work; therefore his own project.

In the fall, students spend considerable time doing library research; using this information to write a research plan and a literary paper covering the topic. They learn to use a word processor in writing the plan and paper. They also begin gathering materials and equipment for the projects, clean a lab area and begin setting up experiments. Conferences with teachers, and seminars with peers are also common at this time. Teachers also assist students in locating materials and equipment, ordering needed materials and equipment, and supervising preparation of solutions and set-up of equipment, and handling of animals.

Later as students perform experiments and record data they write statistical programs for the computer to analyze data. After analyzing the data, students again use the word processor to write results. A conference with the teacher and presenting a seminar to peers concludes the in-school program.

In the Fall, students also begin setting up backboards, making A-V materials, and organizing ideas to display work at a fair or convention.

RESEARCH SCIENCE TEACHERS AND TEACHING

Research teachers must be skilled in recognizing creativity and in promoting learning through individual problem-solving activities. They must encourage students to learn highly sophisticated techniques, and help students sell themselves and their projects to judges and experts who might be able to assist them. These teachers recognize that students may be able to become experts themselves in a narrow range of subject matter, and that this learning may be more important on a given day than regular classroom teaching. Research Science teachers are willing to give of themselves, their time, and talents to a degree that does not seem common among science teachers outside the program.

Teachers plan lessons which apply to all students such as how to write research plans, grants, literary papers, or logs. Teachers also develop plans for using a computer or word proessor and provide deadlines for accomplishment of various tasks. They evaluate the program through evaluating individual students and comparing their success with that of programs in other schools of Brevard County. Post-graduation success of students in universities and careers also has been used to evaluate the program. This has been done on a formal basis by the University of Central Florida. Student sucess can be used to evaluate teachers in the program as well.

The most important strategy for a research teacher is to show genuine concern for the student and his progress, and then to encourage him to succeed. One aspect of this is requiring conferences and seminars on a regular basis in order to keep communications open and to help students avoid the disasters of procrastination. In our Research Science program, one hour per school day is allocated for class time. During this time two instructors are available for consultation. In addition each student is required to spend an average of four additional hours per week in project work. Instructors are available for a minimum of eight additional hours per week for student guidance. Those students not fortunate enough to be in the labs because of the time factor or scheduling problems are expected to spend the same amount of time, although not as much of it will be while instructors are available for assistance. A unique aspect is that the time scheduled is flexible enough for each student to work around other activities such as band, football, or club meetings.

Deadlines are present periodically, but the students can concentrate their efforts at times other than those selected by fellow students. This allows for the participation of these gifted students in many of the varied activities of their choice and they can still give enough time to their research problems to do it and themselves justice.

In early fall teachers hold conferences with students, attend and evaluate seminars, and take students to the library. Teachers demonstrate how to do a library computer search, use catalogues, fill in requisitions, and use the computer and the word processor. Later on, teachers supervise the set-up of projects and actual experiments and evaluate written materials from the students. Another important job of the teacher is to help the students locate experts in their project areas with whom they may communicate by telephone letter, or personal interview.

A unique aspect of the sequence of instruction in the Research Science program is the individuality of student-teacher contacts. Some students are in the very beginning of developing projects and need advice on project selection while other students may be in their third year of project work and may need much more in the way of technical assistance. In the research science classroom teachers avoid the use of a rigidly structured classroom and instruction takes place in a one-to-one situation with very few lectures. This individual instruction is necessary because of the diversity of the topics selected by the students; rarely are two students ever working on the same project. To facilitate positive evolution of the program and hinder negative changes, teachers need to project a positive attitude toward the program and share recognition as widely as possible. Teachers also need to encourage students to set deadlines and avoid procrastination since unnecessary burning of midnight oil seems a major cause of failure to complete projects. Teachers need to see that students do not get behind in other academic areas, since this tends to cause irritation and a negative attitude on the part of parents, other faculty, and administration. If one wanted to cause the failure of the program, one would remove the flexibility of the structure, making the program only available to certain select students, and make the require- ments such that they could not possibly participate in other school functions. This would turn the students into outcasts and drive them away; thus killing the program.

NSF sponsored institutes and various district inservice units have been used to train new teachers in the Research Science Program. In addition, the district Research Science Program guide has sections outlining duties and responsibilities of administrators, teachers, and students, as well as guidelines for student involvement.

The role of teacher education workshops for this program has always been a forum of communication. In these workshops, information is shared concerning deadlines, requirements, new rules and new competitions. In addition, these workshops offer the opportunity to share what is going on in all the different programs throughout the district. These meetings at the beginning of the year serve to generate ideas and create enthusiasm for the upcoming year.

RESOURCES

The written and instructional materials consist primarily of periodicals, reference sources, and scientific journals. Since the first phase of student research involves an extensive literary search to locate sources specifically related to the student's project, these sources provide background materials upon which students build their literary paper. A wide range of very technical college texts are used when applicable to the student's area of research

Materials other than printed matter are used extensively in the Research Science program. Nearly every student has personal contacts with a university profesor at Florida Institute of Technology, University of Central Florida, or the University of Florida. These people serve as reference and guidance personnel. Some students attend symposia such as the U.S. Army, University of Florida Junior Science Engineering and Humanities Symposium, which allows them to visit several labs of their choice and to hear excellent speakers in the field of science and humanities.

GENERAL CALENDAR OF EVENTS

A general calendar of events for the school year would include but not be limited to the following:

I. First Six Weeks

Project selection

A. 4 conferences with a teacher
B. 2-5 trips to research libraries
C. 1 seminar presentation

Due: Research Plan

II. Second Six Weeks

Paper development

A. 4 conferences with a teacher
B. Additional library trips as necessary
C. 1 seminar presentation
D. Due: Literary Paper,
Grant-in-Aid Applications

III. Third Six Weeks

Data Collection

A. 4 conferences with a teacher
B. Individual lab work
C. Data collection and analysis
D. 1 seminar presentation

Due: Preliminary experimental paper
Westinghouse Science Talent Search (for seniors)

IV. Fourth Six Weeks

Project Assembly

A. 4 conferences with a teacher
B. Assemble hardware, display units for project
C. 1 seminar presentation

Due: Project Ready for Presentation

V. Fifth Six Weeks

Competition

A. 4 conferences with a teacher
B. Prepare presentation for oral presentation
C. 1 seminar presentation video taped

Due: Regional Science Fair
State Science Fair
Talent Search
Junior Academy

VI. Sixth Six Weeks

Wrap-Up

A. 4 conferences with a teacher
B. Compile final paper for inclusion into permanent files
C. 1 seminar presentation

Due: Final Paper
Plans for following year.

EVALUATION

Judging at science fairs is not only a matter of seeing who "wins", but a way of evaluating the work of each student. This primarily is done by suggestions made by judges either directly to the student or on his judging card. The primary evaluation of student progress in this program is the professional opinion of the instructor based on weekly conferences, monthly time logs, and daily observations. During the past twelve years, thirty-six research science students from Merritt Island High School have entered the Westinghouse Science Talent Search. Of these, eighteen have placed in the honors group and four have been finalists. One, a top winner, is now attending Stanford University using the scholarship she won.

In the Regional Fair competition, MIHS has averaged thirty-five participants per fair over the past twelve years. In every case MIHS had more winners than all other schools combined. As an example, in 1980 MIHS research students received ten of the possible eleven first place awards at Regional. Of these, all placed in the State Fair competitior ree receiving first place awards with one gaining entry to the Int onal Science and Engineering Fair from the State Fair. In the 1982 lorida State Science and Engineering Fair, Merritt Island students, 11.3% of the participants, took 23% of the place awards. Since the beginning of the program at MIHS, seventeen students have won trips to participate in the International Science and Engineering Fair.

At all of these fairs, students have won many special and place awards including three London International Youth Science Fortnight trips, one trip to the Tokyo Cherry Blossom Science Festival, one trip to the Nobel Prize Ceremonies in Stockholm, Sweden, and one trip to the Virginia Youth Science Camp. Three students have won Navy Cruise Awards, while others have won trips to research facilities from the Army, Navy, Air Force, and one trip to the Thomas Edison 23rd International Birthday Celebration. Two student researchers have had their papers published under their name and co-authored by the senior research scientist with whom they did the work while at Summer Science Research.

Since 1968 98% of research science participants have gone on to higher education. Of these, many have received scholarships attributed, at least partially, to their project work. Many have written letters or told how they feel their success in college has been enhanced by their previous work on a project. One was a student who said that the experience of contacting, conversing, and acquiring gifts of research supplies, materials and equipment through letters and phone calls to researchers, citizens and presidents of companies was invaluable to him as he has been able to use these skills while attending Carnegie-Mellon University. He also received summer employment from one of the companies which supplied him with materials for his project. He feels that having ups and downs with his project helped him to cope with occasional failures in college, and kept him from joining so many of his classmates who dropped out of school. In an evaluation by a University of Central Florida, we found that of the 98% of the student participants going into higher education, over 65% received scholarships for advanced study. Last year, our seventeen graduating Research Science Students received $140,000 in scholarships.

Former students are attending universities from Stanford to Harvard, graduate schools such as Princeton and Cornell, or are graduates in fields such as medicine and nuclear engineering. One student put her writing skills to work as a speech writer for a former Vice-President of the United States.

SUPPORT

Parents provide support, transportation to various events, supervision when several events take place simultaneously, and raise funds for special equipment. Their most valuable contribution comes in the form of encouragement of their children. Without this support very few students would remain in the program for long. The administration of Merritt Island High

School provides support for the program in many ways. Administrators allow instructors academic freedom to handle students as they see fit and view their role as one of support, both financial and moral. They also serve as primary communicators between the program and the county and coordinate inquiry ac: ties with those of other activities in the school and with other faculty members. The allotment of class time for classes with as few as seven students is one sign of support which is not always given in other districts.

The district central administration has helped by providing transportation and organization for student participation in a number of science fairs, from Regionals to the International Science and Engineering Fair. It also supports a limited number of teachers attending and chaperoning students at these activities. The science resource teachers, Mr. Craig Brosius in earlier years, and now Mr. David Murray, have assisted in coordinating these activities on a district basis. Evidence for this district-wide support appears in the current existence of Research Science classes in all ten high schools of the district as well as each of the thirteen junior highs. Mr. David Murray, originally teaching at a local middle school with an excellent Research Science program, has coordinated all science fair activities for our county since becoming resource teacher and assisted in some revisions of the county's Research Science program. He also has helped in providing liason with NASA and various industries in our county as well as with science departments at nearby colleges and universities. He serves on the board of the Florida Foundation for Future Scientists.

Financial support comes from the administration in the form of fund approvals for special equipment and special trips. County funds of $550 per year have been provided to each research science class for equipment, supplies, and travel to libraries and competitions. Brevard County also provides a $1,065 supplement to the teacher's salary for out of school activities.

This school's administration also looks out for the well- being of the program on the county level. Most importantly, administrators attend the science fair and awards ceremonies. Their presence and recognition of student achievement is their most valuable single personal contribution in support of this program. It is our hope that the administration will continue its support especially at the county level where budgeting decisions are made. Their support in this area could result in funding at the same or increased levels, rather than having us suffer expected cut-backs. The school administration could encourage a more positive attitude toward Research Science in teachers of other disciplines, and at the same time encourage Research Science teachers to do the same for other programs. This could have a positive effect on increasing the num er of students involved in the program.

Decisions concerning budget are prescribed by county policy and are uniform throughout the county while curriculum mateials are selected by the local program. Teacher inservice and evaluation are done on the county level by the science resource teacher.

Professional organizations such as NSTA and NABT have played a large role in the development and support of the program. These organizations have provided competitions which served to motivate the students toward success and provided guidelines for the use of dangerous chemicals, laboratory animals, and possibly dangerous equipment such as lasers. Various professional journals such as The Physics Teacher, The Science Teacher, and The American Biology Teacher are used by teachers and students and keep us current with respect to recent advances in various fields of science and science education.

Although there are currently two instructors associated with the Research Science program, many other staff members from the school are supportive and involved. Members of the science department, math department, English department, electronics department, and shop department have all provided assistance on student projects. English teachers proofread papers, math teachers help in projects requiring higher level math or statistics, and shop teachers assist in designing and constructing project components.

Science teachers and others also support the program by having seminars by research students in their classrooms. As an example, a student seminar on pollution in a local setting fits well in ecology classes or in social studies classes. Or a project which uses a computer to show molecular structure is used in a computer math class or a chemistry class. This makes more teachers and students aware of the value of the project and of the capabilities of the researcher involved. The program enjoys outstanding community support and strives to remain responsive to community changes by maintaining contact with local scientific organizations such as the Heart Association, the Technical Engineers Society, and other corporations in the community. This contact is beneficial with students performing services for some of these organizations and the organizations supporting either individual students or the science fair program in general.

EVALUATION

Changing the evaluation system to better reflect goals and needs requires very careful consideration. Evaluation needs to remain invdividualized with emphasis on effort and performance versus capabilities. Evaluating students on the basis of awards penalizes students who choose to investigate topics in the less spectacular areas of science. For a system of evaluation to work, teachers must help students eliminate project ideas which are too difficult and not likely to meet with success for it is difficult to evaluate a student's progress if he never comes to any kind of conclusion. This is also immensely discouraging for the student.

Additional Evaluations which would be useful are accurate surveys of past graduates and determining career choices, successes, and needs. At the present time we are able to keep track of only some students who voluntarily return and keep us posted.

THE FUTURE

Economic conditions make the evolution of this program uncertain since budget reductions affect the program adversely when money is necessary for the development of projects or the purchase of new equipment. On the other hand, if second year science courses are reduced because of budget, Research Science enrollment might increase, although this would further strain the research budget. With a possible rebirth of an emphasis on science, this program should continue on a fairly even keel through these budget cuts. It will mean more fund raising activities on the students' part, and more care in the selection of projects, but these two things are not necesssarily bad, and can actually be positive forces in the evolution of the program. A very positive change that we would like to see in the program is the inclusion of more students. Time requirements made of the students taking upper level classes greatly discourage some from pursuing research. A positive, but possibly unattainable change, would result in inclusion of those students. If more local recognition could be given to successful students, in the media and at school, it might cause the program to be more attractive to those capable students who feel they do not have the time for a project. Research would also benefit those more average students who succeed in science classes but have little opportunity to really "do" and understand science. Perhaps science literary would be enhanced in all students if they participated in Research Science.

If a teacher wanted to start a similar program in another setting they would have to sell the administration on the program by citing examples of how other programs have benefited students. The next step would be to affiliate with some organization, such as NSTA, which could provide a stage for competition. Success of students will sell other students and the administration on the worth of the program. Beginning, a new program requires a positive attitude. A possible good beginning would be to get a few select students involved in inquiry with a helpful professor at a nearby university or perhaps a local doctor or engineer. In the meantime the teacher should be working on developing his school facilities and personnel, and working with just a few students in a field in which the teacher is knowledgeable. A wide range of disciplines must be presented to the high school student so that they can select topics which interest them for students must be enthused to carry out extensive projects.

Although teachers must have considerable subject matter knowledge, just as important is a positive attitude and skill in directing and motivating students. The most effective teacher is not the one who knows the most, but the one who can work with students in an encouraging and gentle way so the students develop ideas from suggestions, activities, and readings. Too much direction and student initiative which is so important to a successful project will be lost. It is also important for the teacher to project to the student that he cares not only about the project but about the student as well.

The rewards for teaching in the Research Science Program are not tangible but lie in the feeling that you have worked together and you may have helped a student go on to bigger and better things. It is much like a parent who did not have a chance to go to college witnessing the college graduation of his child. It feels good to have a student return who is now teaching science or who earned his M.D. or been hired to direct a large corporation. It is also good to feel that your efforts have helped a student into a kind of life whch he wil enjoy as well.

We are indebted to former Principal Robert E. Bruton who encouraged and supported the program from the beginning and Dean Doris E. Glenn who encouraged the writing of the original entry in the Search for Excellence in Science Education for 1982 and who has supported all research students with any school-related problems. (For additional information on the Research Science program as it is implemented throughout the Brevard County school district, see the 1983 NSTA monograph, Centers of Excellence: Portrayals of Six Districts.)

Chapter 3: Creative Inquiry-Based Science Program

By

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Model Laboratory School of Richmond, Kentucky is located in the south-central area of the Kentucky Bluegrass Region. This city of 20,000 promotes a middle-class life style that focuses on two primary industries: agri-business and higher education at Eastern Kentucky University (EKU), the state's third largest institution of higher learning. Many other light industrial businesses are located in Richmond as well. Twenty-two miles south of Lexington, the community exhibits the typical urban sprawl associated with the close geographical relationship of two population centers. Richmond continues to grow despite the economic downturn. Richmond is also influenced by its proximity to the Appalachian Mountain foothills; consequently, there is a blend of the "hand-crafted culture" and that supported by our high technology society.

Model Laboratory School, a supporting department in EKU's College of Education, is administered by a director and assistant director. The staff of forty-two professional employees teaches approximately 750 students in grades preschool through twelve. This well-trained staff of teachers works at appropriate grade-levels and in specific content areas. They provide service to students from the College of Education in their pre-service professional education course requirements by providing opportunities for observation of exemplary teaching and participation in classroom environments. Model Laboratory School also serves as a dissemination and training center for many instructional programs.

The physical structure has laboratory or modified laboratory facilities in each room where science is taught although it does not have such facilities available as a greenhouse, planetarium or animal rooms. Two environmental study areas are available--one within walking distance and the other is the university's 1800 acre outdoor environmental education center located in the Appalachian foothills. Students are transported there two times per year. Students in biology presently tour the greenhouse complex located in EKU's College of Agriculture and, once the university's planetarium becomes operational, the staff and facility will be available for use by our students in both earth science and physics classes.

Enrollment is open to all students and, to avoid an elitist image, all student names are placed on a waiting list. The student population drawn is composed of 50% EKU faculty children and 50% community-at-large children. Each group is further divided evenly by gender. Class size is generally limited to 60, although this number varies slightly from class to class.

My classroom is traditionally rectangular and only 24 feet x 35 feet. A small office and a storage room are on one side with a bank of windows on the opposite wall. Narrow laboratory work counters are located along each side wall and drawers and cabinet space are located below the counters. Each counter contains sinks, electrical outlets, and gas hookups. Large laboratory tables are clustered to accommodate groups of four students. Two other large tables in the center of the room provide dissemination points for materials which are not normally found on shelves. This arrangement provides for easy student access and mobility. A typical demonstration desk is on the blackboard end of the room and a microscope/specimen cabinet, shelving and work table are located at the opposite end. A large fresh-water aquarium is in the room entryway with shelving on the wall above and cabinet space below. I even make use of the ceiling; it becomes a bulletin board and student projects are suspended from the light fixtures as well as from the ceiling. Posters of current interest are attached to the corridor walls outside of the room.

Our old science program was one based on the principles originally established by projects of the sixties such as **BSCS Biology** and **ESCP Earth Science**. It was inquiry oriented but was beginning to show signs of a more textbook-centered approach on my arrival in 1980.

I do not view this "Creative Inquiry-Based Science Program" as new but rather as having evolved from the original inquiry program since inquiry is inherent in Model Laboratory School's total science program. A recent addition incorporating creativity, brain hemisphericity and developmental psychology into the curriculum came about probably because of my own research and training in these areas. It seems apparent that students were enjoying science, but, with this newly incorporated understanding of the learning process, I feel students will learn and have an even better experience in the science classroom.

The move toward teaching from a developmental psychology perspective began with middle school science students in 1979 when Dr. Michael Wavering was hired as a Physical Science instructor. When I was hired in 1980 as Earth and Life Science instructor, I introduced brain hemisphericity and creativity and continued the teaching style introduced by Dr. Wavering. I am not sure that this program should be termed sudden or new. Our creativity-based program was just a different approach.

Originally, I learned inquiry teaching through NSF sponsored institutes and through texts which promoted this learning process. Later, our instructors gained their background through coursework and classroom teaching experience. The current creative knowledge aspect was gained through classroom teaching experience and course work as well as through informal conversations. I have always believed that a classroom should be a place of fun. Obviously, a classroom where lots of activity goes on is going to be more enjoyable than one where only teacher talk occurs. Completion of a course in creativity which emphasized brain hemisphericity congealed many of my loose ends into a style of teaching which promotes creative, hands on experiences as a good way for young people to learn.

Since the inquiry process approach was established from an equipment and text point of view much earlier in the school's history, I simply came in and altered the way events occurred in the classroom. Discussions concerning learning theory and brain hemisphericity take place at the opening of the school year. As events occur throughout the school year, reference is always made to correlate, justify or support the earlier statements. Many project activities, field trips, and other events are proposed, carried out, and related to earlier discussions and activities.

Model Laboratory School is strongly committed to the inclusion of field trip experiences in appropriate curricula. Another committment--long term in nature--is assigning a research paper on a controversial issue in science. Students walk to the university library once a week to complete the research component for the paper. The "creative snack", a day set aside each nine week grading period, represents what each younster learned and is constructed of a "food stuff". It is simply a way of showing what the student has learned and yet allows the students to have a fun experience. The field trip component of the program is dependent on parent volunteers. In addition, because Model serves as a teacher preparation institution, pre-service education majors take part in many activities. The administration encourages and supports all of the various activities which occur in the classroom. In addition, teachers support the field component of my program. Really, we support one another. Again, this is a unique feature of our system which we hope to demonstrate to teachers in public school systems.

The Earth Science field-trip campout to Mammoth Cave could not occur without parent assistance. And, parents are encouraged to join in other field-trip activities as a matter of personal interest. Different parents do volunteer their time to accompany the various groups and a lot of good public relations is established with these well organized field experiences. University students help as well. Because of our situation/association with the College of Education, I use pre-service education majors in many areas--both field work and formal class involvement. Although these students' attendance is intermittent, my students feel free to work with them whenever they are present.

OUR PROGRAM

Students and the activities they complete are the focus of the program. Instructional methods--laboratory sessions, student centered inquiry discussions, student presentations, teacher led discussions, media presentations, and library research with panel discussions and other reports-vary and students express satisfaction. In fact, they report that the class time passes too quickly.

The syllabus with many of those appropriate activities completed for each course is provided below; the list is not inclusive. Students are informed at the time the syllabus is distributed that it is only a guide and that we will generally follow it in the order suggested although changes may occur.

Students generally work in pairs or groups of four. Materials and equipment are readily available and once objectives and the procedures are understood, students move on into the investigative step. Some class time is usually provided for students to complete their laboratory reports. These reports follow scientific format, BUT students are encouraged to be creative in how they fill in the format skeleton.

Many special activities which students enjoy take place in this classroom. The controversial issues paper challenges the students to carry out library research and then put their findings on paper in a logical manner. Although it is a different type of assignment, students often return to indicate their appreciation of the required research and specialized writing in a science class. Field trips are an important part of the curricular activity for each academic area and are scheduled to coincide with specific classroom activities.

Goals for the Science Program at Model (not in order of priority)

1. Foster positive student attitudes towards science
2. Develop scientific literacy and openmindedness
3. Develop an understanding of the nature of science
4. Develop skills in the use of the processes of science.
5. Develop logical reasoning through the use of laboratory experiences which pose questions students must solve and not merely confirm what has already been done.
6. Develop knowledge of science subject matter appropriate to cognitive level.
7. Prepare the student for further study of science at the college level, careers in science, and related fields.
8. Give opportunities for participation in in independent research
9. Encourage creativity in the search for new solutions to both new and old problems.

Students discuss futurism in the area of genetics, alternative energy sources, and current societal issues. Sometimes these focus on anticipated changes based on prior changes. Biology students also investigate what pond water is all about. This ecosystem is examined macroscopically, microscopically and from a chemical analysis perspective. Students investigate the plant community in several ways: quadrant analysis and interpretation is based on their field experience at Maywoods; photosynthesis and osmosis are investigated in particular laboratory experiences; plant growth is examined in two specific units; and animal organization and function are examined during a six week dissection unit. Earth Science Students investigate erosion through use of streamtables. They investigate air, earth and water heat holding potential during a meteorology unit. During a geology unit, they use crayons to investigate how rock types form. Students get a better understanding of density, both in ocean water and in air, through a modification of the colored solutions activity found in the ESS curriculum.

Students complete a controversial issues research paper and, although I request that they not take a stand, I believe after they pursue both sides of specific issues they are forming specific opinions. At this point in their lives I believe it is important that they be able to sort out the facts in issues and therefore approach complex situations with an open mind. Career awareness is dealt with in a special manner. Although specific questions concerning careers are handled as spontaneously as they are raised, I also take time to deal with careers which require course work completed in areas of science and math. Furthermore, last year an EKU Biology Club student attended each class and discussed science and math from an undergaduate student's perspective. My students were very receptive; they asked many good questions.

Earth Science students deal with energy and space-age technology concerns. These concerns are raised during usual topical units and at other times when they might have newsworthy significance. Biology students typically raise questions of concern during topics such as genetics, medicine and related technology, or evolution. However, because of the discussion nature that the classroom atmosphere provides, students might raise an important newsworthy point and spend most or at least some part of a class period on it.

Although a syllabus is provided each student at the opening of each school year, I feel it is more important to learn that with which we deal than cover all the information. This allows for flexibility since we may not cover the topics exactly as listed. However, all topics covered are dealt with in a hands-on approach where students are actively involved. The topics are scientific in nature, but we try to deal with these as they reflect upon us in our present lifestyle.

Students are continuously being confronted with situations which cause them to make decisions. They are formulating a philosphy of life that ultimately affects their community through the decisions they make now--as well as those they will make later. They see and feel the importance of relevance. Last year our student council surveyed students on how the courses relate to their future and on a scale of 1 to 5 (with five being "always") 64% of students in Biology rated a 4 or 5 while 44% of earth science students rated this a 4 or 5. Science is not approached as a "detached" segment. Rather, it is taught as an integral part of a young person's life and that it plays a significant role in shaping values.

Recognizing that individuals are indeed different, many assignments have options. Furthermore, incompletes are given at the end of a grading period if difficulties are identified and an incomplete will alleviate the concern. I hold many student-parent-teacher conferences where the student is a the focal point of the conference. In almost all cases, I refuse to discuss student progress with a parent unless the youngster is present to participate in the discussion.

The creative projects place great emphasis on individual student achievement and student participation and performance is excellent (See the December, 1982 issue of **THE SCIENCE TEACHER**, "Trimming the Creative Tree.") Completion of the laboratory manual is also an individual's attempt at creative expression of what went on in laboratory investigations.

This creative inquiry-based science program is founded on established learning theory principles. Not only does it support the four areas of development psychology, but it has a specific component based on brain hemisphericity. Our society has been taught from a "left-hemisphere" approach entirely too long. I am not advocating that we ignore the left hemisphere, but I insist that the right hemisphere is important also and educators need to begin educating the total brain.

I believe the emphasis is on the student--not on the content. Because I do not believe in the "covering" syndrome, I tell the students that the syllabi are guides and not edicts. As noted, the syllabi presented to students display typical content areas one would expect to find being discussed in any Biology or Earth Science class. I believe that the difference (from the norm) is that my students are approached in another manner--no content is "essential," but rather students need to be assisted in rational understanding and decision-making processes. They need opportunities to become scientifically literate and be able to discuss, manipulate, research, and observe. Any content area will assist them in this manner.

Students play an important role in my classroom. Once the syllabus is established showing general direction for the year, students can offer suggestions. An example is B.W.'s suggestion that we invite his karate instructor in to discuss acupuncture. The topic will be inserted in the animal diversity unit and correlate with development of the nervous system. Acupuncture also is included in our controversial issues research paper list. It is not uncommon for students to suggest that we do a special experiment which would enhance understanding of a specific lesson. Such spontaneity adds zest to classroom life and a student caused change in the original lesson plan may be to the teacher's advantage. Teachable moments should be prized! Students frequently make suggestions and if at all possible, we honor their requests.

Evaluation of any program is very important in order to assess the program's success as well as the success of individual students. Generally, student evaluation is considered in four areas: 1) Quizzes. Scientific literacy is sought through student-generated wordlists. Students are expected to be able to spell, define and use each of the terms in a sentence. 2) Creative projects. Students construct a model, write a poem or narrative, or do something concrete which demonstrates what they learned during the grading period. They also produce and discuss with the class a food product which represents what they learned. 3) Laboratory books. These are examined for scientific literacy as well as creative expression, but they must follow a scientific format. 4) Participation. It seems reasonable that if students are expected to be doing Science in your class that you give them credit for their efforts.

Students also get to evaluate the course and me at the end of the school year. Although this record does not go down in official files, I am pleased with student perceptions of what and how "things" occur in my classroom. Obviously, I have some rough edges, but I also consider that each individual student may perceive events differently from his neighbor.

Program success can be measured in several ways. One important criterion is reference to the increased numbers of students electing to take the next level science course offered. It is significant that Chemistry has gone from one class per year to two. Additionally, physics enrollments also have increased so that the course is offered each year. These enrollment differences represent 33 and 50 per cent increases, respectively.

Management in an inquiry oriented classroom requires organization. A level of tolerance for a large amount of student activity is essential and noise level in the classroom obviously spills out into the corridor at times--so do students! Student evaluations demonstrate that they aren't sure that I always do have control, however. On the other hand, preservice education observers indicate that they see a great deal of intellectual freedom with recognizable control of other behavior.

Student scores on the Comprehensive Test of Basic Skills (CTBS) demonstrate their high academic ability. Their scores average above both the state and national averages. Many students receive full academic scholarships at major universities; many students are cited in the Presidential

Scholarship program (any student with a 27 or higher ACT score qualifies). The 1982 graduating class had five of these recipients. The class of 1983 has two National Merit Scholarship Semifinalists; a number consistent with recent graduating classes. It is fair to conclude that our students are academically well prepared in general terms and that they demonstrate a high rate of success in college.

Because we as educators understand more about learning and patterns of learning, we ought to provide students with as many varied learning activities as possible. This implies that our teaching strategies will likewise be varied. The strategies employed at Model Lab School include, laboratory experimentation, discovery approaches, discrepant events, questioning styles, slides, filmstrips, film discussions, student reports, creative projects and discussions, library work, panel discussions, field trips, and guest lecturers. A varied style of teaching demonstrates to students that the classroom does not have to be the "same old thing" day after day. They tend to stay tuned in for longer periods of the time this way.

Instruction is student oriented with me as a facilitator and with students the focal point. If students are performing lab exercises I attempt to raise questions which make them think about what it is they are d.ing and why they are doing it as they are.

A visitor might observe a teacher doing a variety of things--all related to the inquiry approach to learning. For example, the teacher could be assisting students in a model building activity by asking divergent and appropriate convergent questions; employing better wait-time than perhaps the average teacher; involving the classroom students in the activity--not just talking about what could happen; and listening to students as they deliver their presentations on their creative projects. Whatever it is that a visitor sees, I assure you that it will be different from the teacher and classroom of traditional lecture style!

The administration encourages teachers to develop innovative teaching techniques. They support activities which encourage student understanding of concepts. Examples of this support include recognition and support of the extensive field- trip program instituted at Model in the Earth Science and Biology programs.

Students receive administrative support and encouragement as well. Excused release from school is authorized for attendance at Western Kentucky University's Science Career Days, Kentucky Junior Academy of Science and the Louisville Science Symposium. Students receive excused absences to attend other science related activities held on the EKU campus.

Many of the written materials that I use in my classes were written with specific inquiry processes in mind. I have activities organized for both Earth Science and Biology classes. Packets written include field trip activities for Maywoods Environmental Education Center, Red River Gorge and the Cincinnati Zoo. I have put together a packet of investigations used by students during a six week dissection unit which traces animal development. I also have assembled an investigative plant growth and development unit.

Earth Science students have many activities which allow them to investigate maps and the process of map making, astronomy, geology and forces of weathering and erosion. Laboratory investigations from several sources have been modified to be more inquiry oriented.

Audio-visual productions are incorporated into units as appropriate. **The Search for Solutions** series is used extensively. The Shell Film Library, Bureau of Mines film library and Modern Talking Picture Service are sources of free films used. Because of my personal travels, I have an extensive slide collection upon which I draw.

Outside speakers are invited in to discuss selected topics and to work with specific groups of students. An individual will be discussing acupuncture with biology classes and two or more EKU biology club students will again address my students on the importance of high school science and math courses for most careers--not just to become a scientist. The students are also informed when the Audubon Wildlife Lecture Series is available on campus. Activities are scheduled on a weekly basis and students know in advance how they may schedule their time.

Students complete the ESCP Contour Map Model activity learning more about the meaning of contour lines. Once students understand the concept of slope as provided by contour lines, they move on to an activity interpreting National Park topographic maps. Student groups rotate from table to table investigating specific features of each area. Once they have completed this series of activity sheets we have a map interpretation discussion. Then, student pairs construct a 3-D map representing a landform from a contour map. Each pair of students makes it three dimensional using cardboard strips, colored construction paper and glue. Throughout this time, students have access to their text, a U.S. government publication on topographic maps, and a slide presentation which I made based on tours of the Wisconsin Highway Department and the map making section of the U.S. Geologic Survey. In an activity such as this, students make many decisions about how and when to do the activity.

I attempt to slip into a new unit with a hands-on activity which can be referred to throughout the entire unit. This promotes high student interest; student motivation heightens and we're off. Throughout a three to four week unit students will be involved in a variety of activities--lab experiments, student projects, library work, discussions, films, and slides. At appropriate places, students organize their own list of terms which they consider important; I assist them in the process but do not direct. They do remarkably well highlighting significant terms. In fact, sometimes they insert words which I would not. The day before a quiz, which is geared toward scientific literacy, we have a "bowl" contest or a modified "ball game." One thing is certain--if the class isn't any fun--or at least enjoyable, it will be considered as "boring and too long" by all of the students. Furthermore, the teacher's opinion won't matter.

EVALUATION

Students understand that I do not believe in memorizing facts and tests which measure this. Furthermore, I don't believe in tests. Quizzes in my room are used as devices to encourage scientific literacy. Each class makes up a word list, terms which they believe are important based on our discussions and activities. It is usually limited to twenty words. Students understand that ten of these terms will be orally provided and that they will be expected to spell, define and use each in a sentence. Definition sentences are not totally acceptable; they understand that I am interested in their **use** of the term in a sentence. In this manner, the quiz takes on a very personal approach; they can alter the sentences to their understanding and I discourage dictionary or glossary memorized definitions.

One component of how my students are evaluated concerns participation. I believe that if a student is going to perform in inquiry-oriented activities that some credit needs to be granted for their involvement. I consider much of this classroom particpation as part of the decision-making procedures parallel to those decisions students will make in later life. How students perform on quizzes and complete their laboaratory write-ups also involves the decision making process. In fact, each student has to decide whether or not to complete any assignments. All of these factors result in some kind of teacher evaluation.

Although student achievement on the Comprehensive Test of Basic Skills (CTBS) has not improved significantly since those students who are involved with the creative inquiry based program have been tested, it is important to note that the science test scores have not declined. Less formal evaluation methods include attitude surveys. Comments from the School Climate Survey and scores on the Student Council Faculty Course Evaluation Instrument reflect student satisfaction. Parents also reflect positive comments based on what they hear from their younsters.

The evaluation component of the program involves examination of four areas with an attempt made to balance right and left brain components. Although a true balance is probably not attained, giving students credit for being creative is an improvement over traditional evaluation. The creative projects, of course, are the highlight of each nine-week period! Given the opportunity to be creative, my students have demonstrated tremendous talents. Fortunately, many of these talents have been captured on film and have already been shared with teachers through conferences and journal articles.

Teachers are evaluated on performance in several areas. Because of Model Laboratory School's association with the College of Education and the related work with pre-service education majors as well as an extensive in-service program for practicing educators, it is expected that each teacher's program will be exemplary. It is further expected that teachers will work well with both the students in their charge and other faculty members. Teachers are expected to keep current in their respective fields of expertise by attending and participating actively in state, regional and national conferences, and completing university course work. Finally, conducting research and writing articles for publication is another category considered in the evaluation process.

Many decisions at our school are formulated through sharing ideas during committee work and policy is generally made on consensus. We have recently completed a policy manual which delineates how management will take place. It is revised annually and teacher input is requested. The staff and administration are currently working on a curriculum handbook as well. Our administrators are active professionally in organizations of their specialized fields. Because they believe in the importance of professional involvement, they encourage and support their faculty to be involved as well.

Curriculum materials are selected by department committee or by the individual teacher. Although academic freedom is honored, unusual requests are made with combined faculty-administrative input. Our school has an in-service committee composed of faculty and administration. Some sessions are organized by the administration, however, most are organized with combined effort. Teachers participate in many special programs and conferences at other institutions and are given release time to attend.

A tremendous change which occurred this year was really appreciated. The administration accepted my suggestion and found it feasible to offer the three sections of Biology in the morning. My preparation and lunch period then precede my two sections of Earth Science. This move facilitated both how students could begin classes (more punctual) and how I felt (less rushed). The atmosphere is more relaxed. I am allowed time off to attend professional meetings; I am encouraged to lead workshops and discussions at meetings; I conduct research; and I write for professional publications.

As money for more equipment and materials becomes available, I would anticipate establishing a program with even greater emphasis on hands-on activities. I hope to continue emphasizing the creative project involvement and divergent thinking. The student who cannot think will not succeed. As long as inquiry is demonstrated to be a valued commodity and students are encouraged to take risks, they will continue to develop patterns of thought consistent with their environment. In order to demonstrate even greater relevance, I would like to write some moral dilemma situations and have students interact with their peers over the concepts.

Our planet is a fragile sphere. Emphasis supporting this premise is continually made in both the Earth Science and Biology classes. Students discover this in some laboratory experiences, on field trips, through class discussions, and by observing media presentations. I believe students find the science emphasis at the ninth and tenth grade to be fun and a continuation of their earlier science experiences. Because they do not experience the "only good science course is a tough course" attitude once they get to high school, I believe they continue to feel good about science and continue to enroll in science classes beyond the minimum requirements.

THE FUTURE

The science program at Model will continue to emphasize principles of inquiry learning. Perhaps it is slanted toward creative expressionism more than the normal inquiry program but I believe that each teacher is going to put his personal stamp on the program. I would like to think that the program would continue to emphasize knowledge and learning methodology based on current brain research. Individuals come and go, but hopefully good programs withstand the test of time.

If the program continues to reflect the idea that science is fun and relevant, students will reflect this through conversation with both parents and peers. Students tend to discuss two aspects of education--the very bad and the unique. Allowing students to express themselves in creative ways encourages risk-taking and uniqueness. I believe this does something for self-concept enhancement.

Another benefit to be attained by an improved inquiry program is our department's ability to project an image that these ideas work. Public school teachers will observe our strategies and classroom atmosphere during in-service sessions and positive changes are more likely to take place. The fact that our students are successful academically and also like what they are doing speaks for itself while supporting inquiry teaching and learning.

As I reflect back over 13+ years of teaching science in public schools, I see many areas where I have not changed dramatically. On the other hand, I believe there is one area where I have moved 180 degrees. I have always believed in inquiry as a process and that students learn best by doing manipulative activities. In my early years of teaching, I never got to the inquiry for I was too "hung up" on having students memorize facts as they were doing activities. They did not rebel. In fact, I have been lucky in that my students have always appeared enthusiastic about science, but I could tell that they resented memorizing those fact.

I further believe that I have always held the personal committment that students are important--with them the job of teaching can be pleasant or unpleasant. But without them, there is no job. Why not make it a pleasant experience? Additionally, when students enjoy what they are doing, they too, perform in a more satisfactory manner.

Teachers should continue to promote the concept of student learning through inquiry processes. They should promote student involvement through project completion and other activities; lecture and reading throughout class periods should be discouraged. Let your students know why you are teaching the way you are.

Because the classroom atmosphere changes in an inquiry program, the teacher needs to be able to handle the changes on an individual basis. Students are not always in their seats, the noise level rises, and the activity may spill out into the hallway. In fact, activities may occur throughout the building as the need arises. This will require that management techniques be developed and that students understand the expectations placed on them. An inquiry program requires a lot of trust, not mere faith! And, I have faith that I can make it happen. If I wanted the program to fail I would remove all opportunities for students to express themselves creatively--in written reports, in presentation and in classroom participation. I would force students to complete assignments which demonstrate little or no relevance. I would give pop quizzes; I would discontinue hands-on, inquiry-type activity sessions. I would lecture and insist that students write notes all the time. I would not show slides or films or allow students to play instructional games. The room would appear sterile; no creative projects would be attached to the ceiling or be suspended from light fixtures and the creative snack party would be eliminated from the curriculum. The fun would be gone--and so would I.

An educator becomes involved with many individuals whose cognitive and creative abilities extend along a continuum. It is necessary to recognize where each student is located along this continuum and to assist them in the attainment of a higher level. I view my responsibility in this process as that of a facilitator. Motivational, hands-on activities, concrete in nature, will be helpful in this assistance. A humanistic attitude which is warm but firm, and yet which allows for freedom of choice is necessary for a student to develop a sense of worthiness. This freedom with guidance will lead to a positive affective behavior, reduce discipline problems in the classroom and lead to an improvement in the student's cognitive ability. The bottom line for the above paragraph really says-- Kids come in all sizes, shapes and abilities. Work with them so they can feel good about themselves as they grow and develop. If one expects improvement, one gets improvement.

Because teachers tend to teach as they have been taught I believe active in-service is needed. I believe summer programs where practicing educators are enticed back to the classroom and actually do the activities lead to success.

My advice is this--only those teachers who see benefit in the inquiry program should change their programs--the skeptics establish programs in name only but usually do not apply the philosophical principles. Once a classroom teacher establishes the program, it too can become a model for other science classrooms in the building and school system. A teacher who believes in the program will allow it to be successful, whereas the teacher who is "forced" to adopt it will surely sabotage it.

I believe teacher personality is a significant factor in the success of an inquiry program. Teachers must be willing to share authority with students for what will happen in the classroom. The ultimate responsibility must still rest on the teacher, but "freedoms" are important.

A new teacher should be selected for employment because he or she meets several qualifications. I believe that academic preparation is very important and that course work should be distributed over both the life and physical sciences as well as the humanities. This breadth in preparation should allow for an understanding of environmental issues and consequently the instructor can speak intelligently to most issues when necessary. Furthermore, this academic preparation should allow the instructor to develop a feeling for society and the impact our technology has upon it.

Some articles in **What Research Says to the Science Teacher** have provided support for what I do in my classroom. Attendance at **NSTA** conventions has helped me to be current in science education. The exhibits in computer technology have been particularly good for learning more about new technology and its classroom application. I attempt to provide ideas as well as receive them.

I was asked to chair a Teacher Shop Talk Session at the 1982 KAPS Conference (Kentucky Association for Progress in Science). I have also been invited to speak before student groups on the EKU campus in various Curriculum and Instruciton Department classes; i.e., "The Inquiry Approach for the Gifted/Talented Student," "Creativity as a Motivational Factor," and "Who Is This Man--Piaget--and How Do His Ideas Fit in the Inquiry Program?"

Each member of the science teaching staff is a member of **NSTA** and therefore receives the appropriate grade-level professional journal. Teaching tips and specific information provided in each issue is examined for possible incorporation into our teaching situation. Members of our department have been contributing authors of articles in their areas of expertise. I believe we use these journals as one method for keeping us current in science education.

Several individuals have inspired and encouraged me in my development as a science educator. Mr. Jack Curnow, my former high school science teacher, continues to serve as a mentor, friend and colleague. Dr. James Raffini, University of Wisconsin-Whitewater, assisted me in development of a humanistic and humane way to meet young people and their associated problems. Completion of his course "Disruptive Classroom Behavior" provided academic support to a method of teaching and an attitude toward young people that I believe I intuitively held. The late Dr. Robert B. Sund's belief in young people and their creative talents as well as his philosphy for living set an example for me to follow. Other University of Northern Colorado professors who have helped shape my teaching philosophy include Drs. Leslie Trowbridge, Jay Hackett, George Crockett and Richard Dietz.

EARTH SCIENCE COURSE OUTLINE 1982-83

Date	Content	Typical Learning Activities
Semester I		
Aug. 16-20	Introduction	1) Box Mystery (an investigative activity of several boxes)
		2) Creative Cartoons depict sudent understanding; displayed from the ceiling)
23-27 30-9/3	Landforms	1) Students listen to Landform Model tape set and complete an activity sheet
Sept 7-10	Maps and Mapmaking	2) ESCP Contour Map Model investigation
13-17		3) Topographic map interpretation; investigative worksheets on national parks
20-24		4) ESCP Stereogram Book of Landforms
		5) Construction of 3-D topographic maps
27-Oct 1	Weather	1) Group construction of a hot air balloon
Oct 4-8		2) Loft helium filled balloons
12-15 18-22		3) Work with various pieces of meterology equipment
		4) Model home construction and heating efficiency:
		5) Plot tornado paths
		6) Plot hurricane paths
		7) Record and predict weather
25-29	Astronomy	1) Mobius strip to demonstrate universe goes in all directions
Nov 1-5		2) galaxy model construction ESCP
8-12		3) galaxy card kit
15-19		4) Constella[illegible] tube constructi[illegible]
22-24		5) Spectroscope [illegible]vestiga-tion
		6) Telescope investigation and preparation for daytime and optional study of the night sky
		7) Planetary chart comparison
29-Dec 3	Crustal Forces (Part I)	1) Wood block crustal plate investigation
Dec 6-10	(Plate Tectonics)	2) CEEP Seafloor Spreading model investigation

	13-17		3) Eruption of a volcanic island arc system (plaster-of-paris model)
			4) Plotting volcano and earthquake activity
			5) Map construction of Pangaea
			6) Faults and folding simulation
Jan	4-7	Earth Forces (Part 2)	1) Streamtable investigations
	10-14	(Erosion and	2) Ice cube glacier investigation
	17-21	Weathering)	
	24-28	Rocks and Minerals	1) Streak test investigations
	31-Feb 4		2) Hardness test investigations
Feb	7-11		3) Mineral/rock investigations
	14-18		4) Crystal growing investigations
	21-25		5) Rock simulation (crayon fragments)
	28-Mar 4		6) Periodic Table investigation
			7) Flame Test (ion investigation)
Mar	7-11	Earth Structure (Soil)	1) LaMotte Soil testing of samples
	21-25		2) soil sturcture (sieve and particule size investigation)
	28-31		3) Soil saturation investigation
			4) Soil box construction
Apr	4-8	Oceanography	1) Coriolis Forces
	11-15		2) ESS colored solutions density lab
	18-22		3) Plot ocean depths investigation
	25-29		
May	2-6	Kentucky Landforms	1) Graph profile of state (5 intersecting lines to get a "feel" for the state's relief)
	9-11		
	12-13	Closure Activities	1) Cartooning "What You NOW understand Earth Science

Chapter 4: Inquisitive Chicks: An Inquiry Program for Primary Students

By

Judy Holtz

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The primarily middle-class population of Coral Springs supports good education programs and is equally critical of those of which it does not approve. The community is growing rapidly, due in part to the high quality of education offered by the schools in the area. This city of 100,000 has few commercial areas and, although most wage earners commute to other areas, this is a community with high involvement in many areas of concern and action; education among them . Many of the teachers live in the immediate neighborhood and programs taking place in the schools are well publicized in area newspapers. It is, indeed, both a community and a school where an enriched science program must be taking place. These parents are concerned with science literacy and many students are likely to choose a science oriented career.

Westchester Elementary, a ten year old school with forty teachers, has 800 students in grades kindergarten through five. The budget does not allow for a science teacher so that responsibility lies with the classroom teachers. The academic program is excellent and the teachers and administrative staff are of an exemplary caliber. Teachers and administrators put in many hours of work beyond the school day insuring an exciting experience for students at every grade level. A science room was provided but is used now as a general classroom instead. We are in the process of establishing an Outdoor Learning Laboratory area, funded by a mini-grant, where students will participate in environmental activities. This, again, is being done by classroom teachers rather than a science specialist. There is much pride shown by both the staff and students and parental involvement is very high.

Our students, generally from affluent families, are predominantly white and represent a broad range of ability. Reading levels range from pre-primer one to fourth grade level in our first grade class and math levels are about the same. The children are very eager to learn and have a good attitude toward education, a reflection of home atmosphere and positive school experiences. We are proud of our annual PTA supported Science Fair because many students participate and our district entries do very well. Much interest in research and problem-solving has been generated by the fair and students love the awards provided by the PTA.

OUR BEGINNINGS

My old program did not include a deliberate inquiry approach. Although the Health curriculum for the district does include hatching chicks as one suggested activity, up until this year our first grade had not hatched chicks, nor had it been done, as far as we knew, in the school previous to this time. In fact I had not done any animal behavior experiments. Most of the inquiry in my classroom consisted of activities in the area of physical science and plant activities. Actually, my old program consisted of many activities and, reflectively, a number of inquiry activities which I did not recognize as such at the time. I also relied more heavily than I do now on textbooks for guidance as to what method to use in teaching a concept. Most of my guidance usually led to "right or wrong" questioning rather than true open inquiry as I now believe it should be done. Science was taught as more of a separate content area and not as much integrating was done as I now feel is best for students.

Even though my program was not as good as it could have been, I did have considerable freedom as far as how to teach. For instance I used a different text than the district because I felt the children needed a more challenging program than the one adopted at that time. Most teachers, me included, followed the general district rule requiring all children to have 60 minutes of science instruction each week.

While I felt capable and comfortable with the old program, I sensed we needed something that would stir the childrens' interest and help them learn investigative skills. The children needed to learn how to identify and solve problems and use more skills in data collecting. Graphing, observing and other process skills were not central in forming concepts relating to their environment and students were not aware of when they were using their skills.

We were involved also with a creative writing program and I began seeing science as a good way to help the children use investigative skills while providing a good "research readiness" program, complete with composition skills. Science was to become one way of teaching basic skills such as reading and mathematics in our elementary school. I felt children could be more stimulated to learn and enjoy the excitement stirred by inquiry.

It all started with apples, bandaids, and an antiseptic that didn't work. Dr. Nancy Romance, Broward County Science Supervisor, introduced me to the joy of teaching science through problem-solving techniques. Nancy encouraged me to go on and find why the antiseptic didn't work while showing me how to gain value from failure. The children may not have learned what I intended from that experience but I am still learning from it. After her orientation, it seemed that with every activity I did with my children, I wanted to do more. It became such an enriching and rewarding experience that I wanted it to be better and better and better.

My joy about science as inquiry and my realization of a need for change in my classroom came about rather suddenly through a course which changed my rationale for teaching and my philosophy of learning. Dr. Romance, the instructor of "Teaching Elementary Science" at Nova University, shared many delightful experiences she had had with her students and showed projects and materials produced by seventh and eighth graders; many of which the average student could not do until college. The high level of knowledge achieved by some of these youngsters was astounding.

Even in a school district with 8000 teachers, Dr. Romance has always found time to encourage me and serve as a resource person for all my activities and is the individual from whom I learned inquiry teaching and problem solving techniques. She also has arranged many workshops, including one by Dr. Milo Blecha of the University of Arizona. Dr. Romance has been the force behind most of the Science groups and organizations in the county through which I have met many other science teachers who answer my questions, stimulate me, and even loaned me a chicken brooder. When I ran into a problem about an egg weighing less on the 15th day than the 10th, she provided suggestions leading to explanations. To this day, she continues to be a great source of inspiration.

Dr. Blecha gave me the idea of using chicks for experimenting and taught me inquiry techniques. My first grade team-mates made the whole program even more fun when we all hatched our chicks and they donated them for the experiment. I had many mothers who volunteered their time in my classroom helping children with the lessons for the chicks. Donna Stull, a teacher at Hallandale High School, loaned us a chick brooder, a piece of equipment essential for any activity of this sort and not standard at most schools. Last, but not least, were the joyful faces of delightful children giving me the only reward I really needed. They and their chicks are the real stars of this program.

After I learned how to use a number of teaching skills through participation in workshops, teachers who participated with me in the hatching of chicks learned with the children. We used books from the media center and films from the county film library. I also was inserviced in creative writing by Clarice Lynn, a teacher at my school, and used many of those writing techniques in doing creative writing and composition activities related to our "Inquisitive chicks." Now that teachers on my grade level have experienced this program and been involved in watching the progress of the chicks and the children they seem to be considerably more comfortable while teaching science with an activity approach.

My actual change took place over a few years of gradually learning how children learn through inquiry and discovery. I tried many science activities in my classroom and had considerable contact with secondary science teachers and supervisors. These experiences and contacts inspired a constant updating of my teaching skills through college courses and inservice courses. The more I used these new techniques the more inspiration I had and the more creative I felt.

In changing my classroom, I wanted to design an activity from which my children could learn skills of problem identification and solving, measuring and graphing, and Language Arts. Along with this, I wanted them to have freedom and control over their own investigations. Students were to be free to try what they pleased and to find answers to questions of their own. They were to decide what direction the class would take.

My classroom has individual desks for each child. The room is arranged so that there are eight centers of activities, One is a science center where there is always at least one inquiry activity for the children as well as books, filmstrips, microscope, and other science materials. The classroom is equipped with a sink but no other lab facilities. The walls are covered with colorful backing paper and bulletin boards are all around the room in every available space. Science project displays of class activities are displayed throughout. These show how the children use discovery and inquiry to learn a concept. The other learning centers include reading, mathematics, art, writing/spelling, manipulatives, library, listening, and directed reading.

"Inquisitive chicks" would not have been possible without our principal, Dr. Loretta Smith, who allowed the chicks to remain in the building for an extended amount of time and frequently brought visitors to the classroom to oserve the investigations. This allowed the children to get feedback from outsiders and answer their questions. Many times the outsiders were skeptical of the chicks' capabilities, providing children with a chance to "prove" how smart their chicks were.

The Fort Lauderdale News and the **Forum** newspapers are very eager to report the news of our educated chicks. They have done very nice pieces where the children were featured with the chicks and a good explanation of the program was summarized. Such community support is a very important aspect of our program. Parents were very much involved with the lessons for the chicks. They helped the children write their observations and sat with them while they trained the chicks.

GOALS AND ACTIVITIES

I want students to use investigative skills and to recognize how variables may affect the outcome of experiments. I also want children to recognize that all individuals are different. In doing the activities, students make observations of their experiences, record them, and compare data with others. Conclusions based on data are formed. Then, language arts skills are used in expressing ideas. Students recognize that learning is the outcome of a process and can relate that learning to their role in the environment and appreciate natural phenomena. I want students to appreciate the value of science in our society and desire to learn more.

I want students to begin noting that motivation is a factor in learning and that individuals learn at different rates. When another inquiry activity is introduced, the children should be able to do more independent investigations, form questions to be answered, form hypothesis, and take a greater part in the development of procedures used to solve problems.

"Inquisitive chicks" begins with children choosing a problem and using inquiry for observing, data collecting, analysis, and solutions. Students cooperatively decide what they will do with their chicks and then design and carry out the experiment. The chicks are their charges. Students work on their own or in small, cooperative groups and are free to do investigations they choose. As students work, their perceptions of the investigations are accepted and not judged right or wrong.

First students hatch chicks while comparing the development of the embryo to descriptions in books. Students, in groups of four, then decide what they want to do with the chicks and began planning and doing the actual investigations. Noting results and making conclusions from the data lead to graphing and recording data. After experimenting the children discuss what happened and we decide how we could show other people what we had learned and concluded.

Students learn that some chicks, like people, learn at different rates. The students who teach the chicks that do not learn are not disappointed in them as I had expected. The children whose chicks do learn the appointed task don't brag about it or try to make the others jealous or feel inadequate. I feel very good when I see my students growing in emotional maturity. As they see the role of motivation in chicken learning, they also come to see how their own motivation affects themselves.

By being a behavioral experiment the program teaches how behavior is altered by motivation. The chicks adapt their behavior to eat and, when the chicks are not interested in eating, the children withold food for a few hours, controlling the environment. The children learn how to develop alternatives to situations. This program not only develops student understanding of individual differences and rates by seeing that some chicks learn and some do not, but of the chicks that learn, all take different numbers of lessons.

After the first year program was finished, I found out about a little egg farm which we could have visited and will with our next year's class. Many egg farms do not have fertilized eggs, so it can be hard to find them in some regions. Certainly, other areas have magnificient potential for field trips. The Broward County Media Productions Department photographs our material and makes filmstrips for us. It was difficult to find a developer, but we finally found one that would develop and process the filmstrips at a reasonable price so that each had to pay only $3.00 for their own copy.

Although no textbooks are used, I do use the directions from the incubator on how to hatch eggs. The children also compile a list of resource books used including: **Window Into an Egg,** Geraldine Flanagan; **The Little Red Hen,** Paul Galdone; **Wait and See,** Constantine Georgiou; **Egg to Chick,** Millicent E. Selsam; **Chicken Little Count-to-Ten,** Margaret Friskey; **Katies's Chickens,** Nancy Dingman Watson; **Chicken Licken,** Kenneth McLeish; and **Horton Hatches the Egg,** Dr. Suess. Films which students like include: **The Red Hen An Egg Becomes a Chick, Chicken Little, Chicks and Chickens, Eggs to Market.** The films and books review concepts already taught rather than being a primary teaching resource.

IN OUR CLASSROOM

"Inquisitive chicks" integrates Language arts, math, and science skills for about 10 hours per week for a two and one half month period. During this time children incubate eggs, number them for turning and turn them four times a day. Each chick is marked with an identifying color on its wing feather and each egg is numbered 1, 2, 3, 4 around the middle to facilitate turning. Students arrange for the custodian to turn the eggs at night and the teacher takes them home over the weekends. Children are very concerned that they might break an egg. The whole class researches how the egg is developing and keeps a list of all observations. They write a brief statement on a chart as development proceeds. Students weigh the eggs, record the data and think about the data. When children realize that the eggs are lighter on day 15 than day 10 they are asked to make up explanations. After weighing the egg again, "Were the hypotheses correct?" The students observe hatchings and write creative stories such as "How I Would Feel in the Egg on the Twenty First Day" or "Getting Out!"

Students also record how many days are needed for incubation and make decisions about what they want to do with the chicks. Last year, my class decided to teach them colors, since, of course, the chicks were in school.

So, they made a school for the chicks and prepared colored boxes. The class was divided into groups of four children, each with a chick. The children named the chicks and each small group decided what color they would teach their chick. Each group kept records in their own folders.

To teach color to the chicks students put three boxes in the school; the correct box has food. Chicks are put in the box and allowed to eat. The lesson lasts about 15 minutes and the students withhold food until the lessons are over for the day. These lessons go on as long as needed or desired. Our students spent two weeks last year, but seven weeks this year on this activity. When the chicks are being given lessons, the children are responsible for putting the chick back into the brooder and cleaning the teaching box for the next group. This year, students worked in groups of four, each group deciding what their chick should learn. Two days after the chicks have hatched the children, as groups, have generally decided on an experiment.

Day 1 - Teacher will write, Chicks (can or cannot) learn because... The children answer this question and give support with some facts they have learned about chicks during the unit of study. Their hypotheses are collected and put in a book. Each child will read his or her hypothesis and be able to compare it to the others.

Day 2 - The children paint a box where the chick lesson will take place. We have six different colored construction paper boxes with doors in the sides.

Day 3 - The children, in groups of four with their chick, design a scheme to teach their chick in the "school". They have to learn how to teach a chick. They put food in the correct box, put the chick in, and allow them to eat. If it does not go to the correct box, it is put in again. This process is repeated until the chick learns. After the lesson, the children write observations describing the behavior of the chick. These are kept in a folder.

Day 4 - This is a repeat of Day 3. Most of the chicks are not interested in the food and are not eating. At a class discussion we will decide how to solve our new problem. Last year we kept the food tray closed until the chicks had their lessons.

Day 5 - Same as Day 4 and we continue until the chick learns.

During the hatching students make one book based on their background information of how the chick develops inside the egg and another book of diagrams showing the development. Student record books show their results of each lesson and include the number of lessons given to each chick, the task being learned, and how many lessons it took chicks to learn. Data is compiled from each group of children and put in chart and graph form. Because there is a high involvement of parent volunteers, the lessons are able to take place concurrently during the reading time.

Students draw graphs showing how many lessons each chick was given and how many lessons it took to learn the task. Students review the results and write their conclusion as to whether they think chicks learn and why. They must include a bibliography from our list in the library. A class experience chart is written at the end of the experiment to record procedures used for the experiment and students also make a filmstrip about how the chick develops inside the egg. This filmstrip can include the content children learn and individual conclusions indicating that motivation is a factor in learning.

Students name the chicks, decide what to teach the chicks, and design and build the school for lessons. Students also make observations each day, write their own hypotheses, make diagrams of the chick development, and carry out the lessons for their chick.

When there are problems the children try to solve them themselves and discuss among themselves the possibilities of solutions. Kathryn Drake, another first grade teacher, did an experiment to find out which cereals chicks like best. Her class learned chicks over-whelmingly prefer oatmeal. So my children decided that they would use oatmeal in the lessons for added motivation. Perhaps if a number of different activities for experimenting with chicks were outlined and given to teachers, they may have a source from which to choose and guidelines to follow. It is not hard to do and has marvelous results. All the results are recorded so that each class may share them. Each year, as new students do this activity, they may choose something else to do with the chicks. It will be that class's decision.

The content emphasizes how a chick develops in the egg and students are taught what factors need to be present in the incubation and how this compares with natural incubation. Then, as each day passes, the children learn through observation and reading how the embryo is developing. The facts are written on a chart and displayed in the room where it can be observed and reviewed. The children also learn that a chicken is a bird and learn the characteristics of that animal. They identify other animals as being birds and listen to various bird calls of South Florida. As a review, the children make a filmstrip with each child producing one frame. This filmstrip teaches others how to incubate and how the chick hatches from the egg. The filmstrip is photographed, processed, and given to each child as well as shared with other classes. One filmstrip is placed in the school media center.

The children won a "superior" award for the Westchester Elementary Science Fair and won first place in the Broward County Science Fair in the category Class Projects, Life Science. The project was also awarded runner-up for best in show. Many of the children entered posters in various contests and won individual prizes. Six of my children also won prizes for individual entries in the Science Fair. And, not only do they do well at fairs, last year my students were one year above grade level on the California Achievement Test. I also evaluate their problem solving skills by their performance in subsequent inquiry activities. Evidence of achievement is evident in students interest in science and a short achievement test. On this test fifty-five percent of the children understood that food was the motivating factor that affected the chick behavior. Five percent attempted to provide a rationale as to why some did not learn the color.

The child's participation in the entire project is used to determine success in most instances. A good inquiry teaching tool not only helps children find answers, it also stimulates more questions and motivates additional problem solving as a result.

After completing this program, students better understand problem solving techniques and are able to pursue questions raised by their own activities. I hope more interest will be generated in Science and Science teaching so that elementary school classrooms can see more inquiry teaching in the future.

No budget was provided for this program but it is very inexpensive. Eggs are $5.00 a dozen and brooders are about $50.00-$100.00 Through inservice arranged by Dr. Nancy Romance, Science Supervisor, and Jim Carswell, Curriculum Planner, I have shared this program with other teachers in the county, state, and nation.

As our program changes, we are emphasizing more problem solving and inquiry. In the past year I have used this method where I never had before and I have found that much subject matter is easily adaptable to this method, particularly as I became more familiar with questioning techniques.

With the excitement generated by this program and the interest shown by supervisors and the general public, other teachers have become interested in the techniques. I intend to continue using it in my inservice presentations, as it has already been presented locally, at our Florida Association of Science Teachers Convention, and at the 1982 National Science Teachers Association meeting. It is my hope that some of those individuals use this program in their own schools.

Teachers provide the materials, resources, and facilities necessary for the students to perform lessons. They also arrange for parent volunteers to help children with lessons and provide observation forms so that the children can make observations and record them quickly and with maximum ease.

The teacher's role is to act as a consultant to the children, helping them locate materials such as films, books, filmstrips, and magazines available in the school and community about the hatching of chicks. The teacher should lead informal discussions with the students to assess how much the children know about how chicks develop. The teacher should also raise questions about what students see, how they think it is happening, and what they think will happen. Discussion usually reveals that they know nothing about the subject and provides an opening leading to background information needing to be covered with the students doing as much of the research as possible. When asked how big they thought the chick was at the beginning of incubation, students may guess as big as the egg itself. They envision the chick fully grown, waiting for the time to appear. By asking questions such as "How big is it?" and "What does it look like?" the children have questions to answer and begin to find out other information and make guesses about what is happening each day. When evaluating the progress of children, the teacher should assess what needs the children have and provide for them to become better educated in the area where the need is shown.

The teacher must model Inquiry techniques. Students must find out rather than be told and must ask questions of the teacher and other students. They should be willing to risk a guess and recognize mistakes with all information noted and recorded for future reference. Students should advise the teacher of materials needed and feel free to do self-initiated investigations. If a question arises, the teacher must not answer or evaluate it; she should help the children search for answers. When doing this activity with young children, they may not yet be prepared to pose the problem themselves, they may need help. Inquiry methods range from teacher posed questions to complete freedom for the students to pose their own questions of interest and pursue the topic. The teacher must aid the students in the procedures for investigation in order to teach them how to use inquiry. By repeatedly dealing with different curricula in this manner, children will grow into expert problem solvers of the future.

The advice I would give to another teacher is, learn along with the children, let them know your hypotheses, as it is fun for them to find out you don't know too. They feel more free to investigate rather than to give the right answer when they think you don't know it and you are learning with them.

If I wanted to make my program fail I would tell the children exactly what they should do or simply teach outcomes rather than how to identify, investigate, and solve problems.

A new teacher should have knowledge of good questioning techniques and be willing to let the children do activities rather than be told. They should have a background in scientific process skills and what they are and should have used them in some way during their undergraduate work.

The skills of inquiry teaching should be included in undergraduate work for Elementary Education certification and more school districts should be offering inquiry techniques through inservice.

Through workshops, I learned inquiry techniques. I also have learned by giving workshops to other teachers and found many using the approach in their classrooms. I plan to continue giving these workshops in the future so that teachers may share these experiences with their children. However, I do feel teachers should be paid for this kind of training. Perhaps some extra funding could be made available for those elementary teachers who would like to develop their expertise in problem solving and inquiry. Through bringing in outside experts from colleges, we could have a good inquiry program throughout the school districts of our nation and thus make more students able to use inquiry.

Other than those awards and recognition given to me and my children through organizations, the intrinsic value has been to see children learn on their own and discover new relationships among the world around them.

In addition to winning awards we have had articles in the **Forum Newspaper** and the **Fort Lauderdale News, Miami Herald,** and **Quad City News.** We have letters from the Attorney General of The State of Florida, Senator Lawton Chiles, and Education Commissioner Ralph Turlington. Recognition from the Broward County School Board and the Florida Association of Science Teahers Outstanding Educator Award, 1982, have been most memorable.

From **Science and Children** I have adopted many good ideas for my classroom. I have also had an article published in it. I feel it is important for classroom teachers to present their ideas to others in the science education community. From other teachers I learn of childrens' needs and how I might meet them. This is professionalism in action.

Chapter 5: Science Projects Seminar

By

Ann Justus

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Camelback High School serves northeast Phoenix, a community of middle and upper-middle class population. However, the school district has an open-enrollment policy which allows students to attend any school; a policy resulting in a considerable influx of students from other areas. The students' needs and abilities have dictated a strong academic program stressing preparation for college. While student population in our area has decreased our enrollment has been rather constant around 3000 because of increased numbers of out-of-district students.

Parents and community strongly support the school philosophy and program. This support, a qualified faculty, and an efficient staff have helped Camelback High School earn the reputation of being an excellent school even though in the past two years three schools in the district have been closed and litigation is forcing one of the inner city schools to be reopened. This has created growing tension among students and faculty as involuntary transfers appear likely.

Our students in grades 9 through 12 are served by 150 faculty members, 11 counselors, and 30 staff members. The original buildings are 30 years old and several new buildings have been added as needed. The structures are typical desert, pre-energy-crunch, styles -- lone, two-story, one-room-wide buildings, each room opening outside and with wide overhangs protecting outdoor lockers. All rooms have many windows. There are two newer science rooms, seven original ones, an inadequate portable building, and a too-small greenhouse. Laboratories are satisfactory and well equipped and the atmosphere is generally academic with pleasant student-student and student-teacher relationships. Although only one year of science is required, 75% of our students are taking two years of science.

OUR BEGINNINGS

After special education for low achievers was state-mandated, there was increasing recognition of the need to provide special education for the gifted as well. The state Department of Education had set standards for the gifted and, ten years ago, the district recognized that there were a considerable number of students being neglected. So, when the district initiated a program for gifted students, each school chose a plan to best meet the needs of its students. This was a new program for the eleven high schools and each developed a unique approach. At Camelback four teachers and a counselor determined that we needed four independent study seminars as an appropriate beginning. Science was one of the seminars. We called it "Science Projects Seminar."

When I first was asked to attend a meeting to discuss the possibility of gifted classes I assumed nothing would come of it. The following summer we had a workshop to plan the seminars for the next year. It was rather sudden to me because I did not expect it to actually happen. When it happened, I had complete freedom in choosing the objectives and activities of the Science Projects Seminar and I did so with considerable input.

My initial inspiration was the challenge of developing a new program, a program with no precedent in our school. It was also an inspiration to have this expression of confidence from the administration. Many of my ideas came about in a series of workshops, although I have gained several useful ideas from journals such as **The Science Teacher**.

Many ideas came from the counselor in charge of the gifted, a person who was a constant source of help with enrollment, budget, and encouragement as was the science department head who helped me establish the class in the science department. On other campuses the gifted program frequently was separate from all departments--a separation which is not optional, in my opinion. Many members of the science faculty were helpful with equipment, expertise, and ideas. Even my husband was helpful running errands and providing understanding that developing The Science Projects Seminar was not an easy task.

A preliminary workshop just prior to the opening of school established goals, objectives, and initial plans for the gifted seminars. The seminar itself began with five or six students and grew steadily as gifted students were identified. The first year was difficult for me as well as the students. We were all frustrated by the unstructured independent study; they wanted me to tell them what to do each day and I wanted to tell them. But, making their own plans was an important part of the planned program so I persisted. Needless to say, most of that first year was spent doing what they already knew how to do--literature research and report writing. I was bored; the class was dull, lifeless, and not capitalizing on the real excitement of science and research. So, I began encouraging and rewarding laboratory research. I have continued in this direction ever since.

By the fourth year several students had projects entered in the Regional Science Fair. Although the results were not great, a second and fourth place, they did provide an impetus for some students. Truthfully, I was often quite unprepared to help them with their presentations but, after the first effort I realized, as did the students, that my students could do as well as what we saw at the fair. I also realized I must emphasize research specifically leading to projects for competition. This was the point where I finally let go of my ties to the traditional structured class and became more willing to give students the freedom necesary for truly doing science research. I also realized that I had not let the class become different enough to warrant its purpose. If the students were not having a unique and special experience then they were not making the most of their talents and the class and I had failed.

As a result of my ideas leading to changes in class structure, in 1976 we had better results at the fair with one student winning first place in his section and a four year scholarship to the university. The next year a student won the sweepstakes and we found the great reward of attending the

International Science and Engineering Fair where he won three awards. That momentum has continued into the present Science Projects Seminar. Still, experimental research is not required but is strongly encouraged.

I developed the Research Projects class by trial and error and considerable literature research and study. Our workshop material made many references to gifted students which I found useless. I knew what they were like and their characteristics but, what I didn't know was what kind of work to have them do. From the beginning changes have been constant with some being made on an intuitive basis, some based on student suggestions, and some because a change was obviously needed. I was fortunate in having a broad background in the sciences, but I still feel quite unprepared for some of the things students choose to study. When I am at a loss, I look elsewhere for help. I even hired my daughter to write a math and computer unit for the first year.

For several years seminar teachers had one less class and two preparation periods to enable a more reasonable operation of an independent study group. During that time, I taught three advanced chemistry classes and the Projects class. For the past two years, though, I have had to give up the second preparation period and teach another chemistry class. I consider this a removal of support and lack of recognition of the excess work required of extension and serious laboratory work. For several years also there was a small budget for the entire gifted program because of state aid, but now that has been reallocated. The class is supported only from the science budget and subsidized by my time after school hours and on weekends.

OUR PROGRAM

Science students need to understand the regularity of nature and how these regularities are observed, explained, explored, and measured. Students must understand the workings and nature of science. It is important for young people to recognize the pervasive role of science in our past, present, and future development and the effects of science on progress and human endeavor. They need to know the scope of career choices in science and technology and recognize that they will eventually inherit the responsibilities of sustaining and continuing the "good life" they now have. Not many will become scientists but they all will, undoubtedly, be confronted with decisions of a scientific nature which they must make with knowledge and reason and an understanding of their own emotions.

Science literacy is a key to making these decisions. All students, including the college bound, need to have as good a preparation in science as can be given. This is not just content; more importantly, they must be able to use and appreciate science. Students learn and become more proficient in selecting and directing their own study, in keeping records, and keeping up with new developments. Students share interests, ideas, and problems with a group and then apply concepts to problems they have identified. Researching the scientific literature and writing a technical report emphasizes the diversity and complexity of science.

SOME GOALS AND OBJECTIVES FOR THE SCIENCE PROJECTS SEMINAR

GOALS: To provide experience in self-selected and self-directed science activity.

1. To encourage students to engage in research at their own levels and to develop self reliance in pursuing individual interests.
2. To promote activity in a) applying concepts from regular science classes to other situations, b) more in-depth study of the concepts from science classes, c) exploring materials not used and ideas not emphasized in other science classes, and d) use of specialized science equipment.
3. To establish methods of record keeping and presentation.
4. To maintain an atmosphere of interest in new developments in science and technology.
5. To encourage the sharing of interests, ideas and problems with a group.
6. To provide an opportunity to explore science-related careers.
7. To encourage participation in science competitions.

OBJECTIVES: The nature of independent study precludes a definitive listing of objectives. Activities will be so devised and directed that a portion of these performances will be included for each student. The seminar activities enable students to work independently as they:

1. Choose and cooperate in planning a program of study.
2. Show active continuity in a chosen study program.
3. Devise laboratory experiments, collect data and present results in writing (and orally to the group if of general interest.)
4. Show skill in use of specialized equipment.
5. Demonstrate proficiency in use of the computer and programming.
6. Research the literature for selected topics to a suitable degree.
7. Participate in group activities of common interest.
8. Make evaluations and judgments based on appropriate data.

9. Present final results in writing and to the class, and through competition

The class has high ability freshmen through seniors, many gifted, but all with a special interest in science. Students may take the class as many years as will fit into their schedules although, in the ten years of the class, only two students have been in the class a full four years. Many students elect more than one year though. The class usually numbers around 20 and student attitudes are positive because they like the freedom and scope of a small and somewhat unstructured class. They feel special in the class and have considerable intellectual freedom to pursue their own education.

Some students spend a moderate amount of money on projects, but most rely on what the school can supply. If special equipment is needed, then students must supply the funds. This is one of their choices.

Students in the projects class experience a considerable range of peer interaction and levels of ability. With freshmen to seniors, unusual working conditions, and a climate of increased personal responsibility, many positive interactions occur.

At the beginning of the year we go through a decision-making process. Several local plans for future development are presented, placed on a large city map, discussed and then voted on. The students have been designated to vote as teenagers, senior citizens, business men, cacti, air, water, farmers, desert, or any other variable which makes sense to them. Each states his reason for his vote--bringing up many science-related problems and issues. Issues that are in the news at the same time get special emphasis. This focus on social issues and careers is a way of getting the class to work as a unit and getting some issues in front of students. No other specific emphasis is given to careers although an occasional film or speaker provides awareness of a particular occupation. I do hope they are seeing a happy, eager, and professional science teacher all the time.

Science as Inquiry is the major activity and purpose of the class. As students pursue their chosen study and begin to focus on a specific problem, each develops a unique process to fit his problem and purposes. This is one of the most valuable learning situations students encounter in the class. When a student begins to analyze data or interpret what he has found, he faces the reality of what he has actually learned or gained and what it means to himself and society. True inquiry usually starts at this point.

Scientific research and inquiry is problem-centered and flexible. The variety of problems students choose to study usually include some that are of local relevance. For example, a student studied the effects of formaldehyde on rats after learning of the problem with insulation in a new housing development. Students often study themselves and peers through behavioral projects. Last year there were two such studies, one of which won the regional sweepstakes and an international award as well.

Other studies are sometimes directly related to improvements in the human environment or people in general. I like to think all science research is working for the betterment of people through increased knowledge. Regardless of the nature of the project, individualized instruction is central to independent research and study and students must plan their own goals and work schedules. I am available to advise but I rarely insist if a student rejects my help. I keep reminding them this is their big chance to show what they can do. In this way, all project work is individualized and personalized.

Students often begin working in cooperative small groups. These groups frequently break apart and students become more independent as their studies develop. One group remaining this year is three students remodeling a hovercraft in a cooperative effort. Students are free to work alone or together, on whatever project, and to the depth they desire. As a result, students are able to work at their own level, in their own way much as developmental psychology would demand.

Students select a study of particular interest, plan the work, and carry out literature and/or laboratory research. In the process they make a lot of decisions. Students who enter a satisfactory project in the spring Science Fair make a grade of A. During the research process content suitable to the individual studies is obtained and used. For example, if a student wishes to use the computer then he must learn computer rules, language, and use. Not all students will be involved with any particular content.

Every book and article I have read about "how to do an experiment or project" states that the study and research must come first. I agree with this from an intellectual view point, but students do not always have enough background, confidence, or attention span to do this. I have found better results by using the "hands-on" first even if it is unrelated to what eventually will be done. So, I do not require that students carry out extensive study before beginning experimentation. In fact, I urge them to start some kind of work as soon as possible because I have found this builds confidence and gives them something to do while they are getting a focus on the long-range study.

The relevancy and success of the program depends on the relevancy of the choices students make for their own studies. If they won't choose or choose a poor study I try to guide them in another direction. But, their freedom of choice keeps the students going and the program relevant. Before each class I read weekly reports. Five are turned in each day so this is an easy job and I can stay caught up. During class I am most often conferring with students, checking what they are doing, getting equipment, teaching how equipment works and is used, or teaching techniques such as making solutions. I also look at and discusss computer programs, look for the locker keys, make lists of supplies to buy after school, and help clean the rat cages. Sometimes the trivia of showing a student how to put the camera on the microscope or going to the storeroom drives me crazy. But, they all need to learn. After class I collapse! Fortunately I have lunch just prior to this class so my energy is high even though the seminar follows the four morning chemistry classes.

Each day twenty students check in at my desk in the lab and begin their work. Sometimes we meet in a group for announcements and student progress reports or to see a film. This year, typically you would see three boys rush to the auto shop to continue work on a hovercraft they are redesigning. Three students may be tending to their rats and several more are standing in line to talk to me. Others are tending fish before going to the library or preparing their log for the week. Three students are at the computers while the remaining students are working at assorted projects. Two are arguing. It does seem that I have more than twenty students most of the time. I also am constantly trying to find something and to do three things at once but I love it. I encourage students to devise equipment and make-do with what we have. So, a visitor may see usual things -- such as a large rubber raft (from state surplus) being cut for the hovercraft skirts. This 4 x 9 ft. craft is taking a lot of time. Once projects are underway students don't want too many demands on their time, so one day is similar to another. It seems like the shortest period of the day to me and them. This pattern continues throughout the year.

OUR GENERAL CALENDAR

Sept:	Several days of group activities to get acquainted. Define the area of study. Outline a plan of work. Get equipment ready and start research/experimentation.
Oct:	Select two projects from the spring fair to enter in the Arizona State Fair youth competition. (Not the Science Fair)
Nov:	Assign Space Shuttle Competition for semester exam. Have several discussion sessions about past competitions. The class had a winner each of the first two years of competition.
Jan:	End of semester. Some students leave, others enter.
Feb:	Learn results of Space Shuttle.
March:	Participate in Arizona State University Engineering Design and Testing competition one Saturday.
April:	THE SCIENCE FAIR!

I am a resource person for students in the process of planning and defining their work. I set the requirements for evaluation, read and react to their weekly reports, and constantly try to find ways to improve the process. Students usually prepare their own lab materials but I often must help students make contacts with resource people outside of school. I take full responsibility for care and use of expensive equipment. The projects class uses a typical chemistry classroom, adjoining laboratory and stockroom. The projects are crowded on stands, in hoods, on counters, and just everywhere. The animals--rats, mice, frogs, fish and newts-- take up considerable space but all science facilities are available to us. Since all science material and equipment are available for student use, the science faculty is obviously cooperative in lending equipment. We have an unusual store room of "collectables" since I am not the only beach comber or pack rat on the science faculty. Dangerous chemicals are in a separate stockroom under my control, however. We are very crowded and equipment is stored in cupboards in the lab. Students are allowed access to equipment after I have established their knowledge, skill, and awareness of safety factors. Tools, cameras, microscopes, and expensive equipment are kept secure and under my control as well. Students must clean up and put away as needed for, if the chemistry classes are to be in the lab the next day, all counters must be left clean and clear. I also do considerable cleaning, though. Tidiness is not one of the virtues of this class but it is obvious that this is a room where much is done and acomplished. We really need an animal room, a more suitable greenhouse and a darkroom. I don't take responsibility for everything, though. Students are encouraged to do extra lab work after school to extend their experience and they take considerable responsibility for their own learning.

EVALUATION

Students are evaluated on how well they meet their responsibilities in choosing work of a suitable level; and how they plan and carry out their work, turn in their record book weekly, and maintain serious and mature behavior. Each week students complete a self-evaluation sheet and I add my evaluation. If we differ in the evaluations a discussion of the reason follows. Grades tend to be very high.

I was surprised when I realized a few years ago that students have never been in a situation where they can fail without severe consequences of some kind. High level students rarely fail at anything, especially routine lab work, and they begin to relax when they realize that failure of an experiment is not a personal failure. Actually, I am primarily interested in how they go about the work and not the individual outcomes when I evaluate their efforts.

I try to avoid telling a student his idea is not good. Instead since self-evaluation is a critical goal, I try to turn the discussion so the student makes his own assessment and evaluation. I avoid answering certain questions if I feel the student needs to make a decision. Excessive rules and directions are avoided. Instead of giving a negative opinion of a student's poor efforts I suggest that the work may be too difficult for him. This usually gets immediate improvement. I also avoid wearing uncomfortable shoes.

Students evaluate their own understanding of content and experimental results as well as those of others. They seek to establish applications and future developments and uses but their focus is always on the here-and-now and the personal. This is important, for ultimately it is the individual student goals and needs that must be met-- not those of the class.

During the first three years the seminars were evaluated with teacher, students, and parent evaluation forms. After that time the seminars seemed well established and I have not conducted much program evaluation since. I have not been given time or suggestions to do so but I do seek and listen to comments. I would like more.

For program evaluation, surveys of past graduates would be very useful. I do have some contact with past students and their evaluations are positive; but I don't really know the value of the program to most who have been in the class. I would like to know if the class was beneficial to them, how it was beneficial, and what they think would improve it.

A few years ago I felt high school research was of no value. Now my attitudes toward student research, projects, and science fairs have changed completely and I feel it adds an important and significant facet to a student's knowledge. I feel that a research project should not be an after-school hobby-type activity. I once opposed science fairs because I had not seen how important the experience can be to students. Succesful participation in fairs promotes the science program and provides recognition for student success, not equal to sports performance in our school, but getting there. I now recognize a greater potential of the teenagers' contribution to knowledge. Administrative support is very strong and very necessary. Our administration allows the class to be held if 20 or more register and they allow me to take trips which students win for us. That they are pleased with the recognition and awards students receive is obvious, for, when I ask for help I usually get prompt, positive responses. The administration helps with budget as well. Our budget needs are small but we truly need flexibility. Last year I applied for a grant from the Arizona Association of Gifted and Talented organization to purchase an old used water hovercraft for students to redesign and fix up for land. It had a light aircraft engine, its own trailer and looked terrible. We were granted $390 to purchase the craft. It is keeping three students very busy this year - and will be valuable in years to come. The point is; some needs arise unexpectedly and the usual, established budget will not allow these expenditures. We frequently need hardward, grocery, and medical items right now; we can't wait. An administration that recognizes this is a great necessity.

The principal's door is always open, and he is easy to approach. He treats teachers as professionals. He also takes his lunch with the teachers. This is one of his greatest influences! Although the administration is supportive and the class will continue with present goals as far as I can determine at this time, I see the class being dropped when registration shows less than 20 students. Next year more may be required because of the shrinking budget. Past successes do not mean anything when decisions are made with numbers. I think the shrinking budget will eventually eliminate the class and twenty students a year will be deprived of a valuable part of their education -- a part that cannot be replaced by traditional classes. Parents also are helpful and supportive although I find through the years parents become involved only if they are asked. I always ask for help at science fair time with transportation and I encourage students to get parental help in tracking down magazine and journal articles at the Arizona State University library.

BEGINNING A PROGRAM

Attendance at two workshops I have held indicated teachers are interested in student research. However, what I have done cannot be done without a class such as I have. Projects should not have to be subsidized by both teacher and student time. If the administration does not allow time I see no way for a teacher to get involved, and no reason. If I wanted to start this program in another school and, given administration, department head and science faculty approval and cooperation and a teacher willing and eager to invest excess time, these actions could get a class started:

1. Advertise the class prior to registration. Make it clear this class does not replace the regular science classes. This is very important to prevent competition and discontent in the faculty.
2. Canvass interested students.
3. Contact current science teachers for probable success of interested students.
4. Select the least number possible of top candidates - the older the better for a start.

5. If possible have prospective participants attend a science fair.
6. Teacher (or teachers - ideal for team teaching) and students should read one or more books about projects to establish a plan of action. Group discussions will clarify procedures. There is no best procedure - just one that works for a group.
7. Require a permanent record book to be turned in weekly or at some short interval.
8. Have teacher approval before work is started. Take care with dangerous procedures.
9. Stress the importance of background information and assist with literature research techniques.
10. Good luck. (Kids will surprise you with what they can do.)

A strong science background is a must, not mastery of all subjects but enough knowledge to know where to get help. Laboratory and research techniques are necessary and use of hand and power tools is highly beneficial. A new teacher probably should not attempt a class like this one although a possible exception could be a teacher who had been in such a class before or who had extensive research experience. Even though I have been teaching this class for a few years, I need more and better introductory activities for the first two or three weeks to ease the adjustment of new members. It is easy for students who were in the class previously (they can take all four years if they can so arrange schedules), but newcomers, especially freshmen, need time to realize what is to be done and to adjust to the less-structured atmosphere. I also need more "how to" books and articles. Over the years I have collected single copies of very useful books and manuals and have lost most of them. Since I have not used a check-out system books do gradually disappear. For example, last year an excellent book on holography disappeared. I rationalize that if a student takes such a book he might use it but, I sure need them myself.

There has never been an aide for my part of the program, but one would be highly beneficial. Originally there was an aide to keep track of placements, supplies and budget fo the four seminars. She was very helpful with field trips, letters and telephone calls. Increased planning/research time for me would enable me to have more and better input as well. I have trouble providing help and student needs for specialized studies. And, increased planning time would, perhaps, enable me to be more innovative. Sometimes I think innovation is inversely proportional to frustration! The pride and satisfaction I experience when students enter competition, whether they win or not, are extremely rewarding. I feel rewarded when a student accepts a challenging task, completes it, and presents it for others to consider or evaluate. When students do win some recognition they are amazed as well. Their pride invariably results in greater maturity and self-concept. This is a learning process not many high schoolers experience.

It is rewarding to have students return after graduation to express their appreciation for the class. I also find I am much closer to this group than students in other classes and I try to keep up with many of them after they graduate. Most of them were also in my chemistry class, adding to my understanding of them as individuals.

There was a reward of sorts when a mother presented me with a special gift. Her son had won the sweepstakes with a project involving rats, many rats, and she made a needle point plaque with cute rats and the legend, "The rat race is over and the rats won!". Other recognition has come in being named Outstanding Science Teacher of 1978 by the Arizona-Nevada Academy of Science and Runner-up to Arizona Teacher of the Year in 1980, I also have been invited to make presentations at four state conventions, two for Arizona Association of Gifted and Talented and two for ASTA. Receiving the Super Teacher Award given at the 1982 Senior Awards Program was most gratifying as well. Professional organizations are also important as I make regular use of articles and suggestions in **The Science Teacher** and my copies are available for student use. A student recently began a plant cloning experiment because of an article in **TST**. And, finally, **NSTA**, a professional organization, gave me the opportunity to say all this. I'd like to end as my program always ends, with student achievements.

STUDENT ACCOMPLISHMENTS IN THE PROGRAM:

* 1 state first place winner in computer programming
* WINNER AT THE INTERNATIONAL SWEEPSTAKES in computer programming
* A sophmore who authored a textbook in organic chemistry
* 194 awards at Central Arizona Regional Science and Engineering Fair
* 23 first places in 7 SWEEPSTAKES which were then entered in the International Science and Engineering Fair
* 7 International Science and Engineering Fair awards
* 10 academic scholarships to Arizona State University
* 1 semifinalist in Westinghouse Science Talent Search
* 2 regional winners of Space Shuttle Competition
* 2 presentors at Army Regional Junior Science and Humanities Symposium
* 1 of the top 6 winners of Science and Humanities Symposium
* 1 of 10 top Edison-McGraw winners for the United States and Canada
* 6 science winners at the Arizona State Fair
* 1 representative of Arizona at the West Virginia Science Camp
* 1 Earth watch winner for two weeks at an Archeological Dig in Montana
* Many awards at the Engineering Competition Day sponsored by the Engineering Department at ASU each year.

Chapter 6: Methods and Applications of Science

By

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Williston Northampton, an independent school with 430 students in grades 9-12 is now co-educational. A merger of Williston Academy and Northampton School for Girls created the present school with its diverse student population. One fourth of the students come from outside of the United States and the remaining three-fourths represent 26 states. In general the students are planning to attend college after high school.

The school is led by Christopher C...tery, headmaster, with department heads and what must be a more-or-less standard number of administrative support personal. Williston Northampton has an upper school of grades 9 to 12 and a middle school for grades 7 and 8. The campus includes several buildings and a great deal of space outdoors for sports and other activities. The Arts and Science Building with attached green-house is near a pond used for ecological study by all of the biology classes.

Methods and Applications of Science, designed for non-science, mathematically anxious students, enables students to fulfill their second year of science requirement--two years of science for gradua[illegible] with one of these being a junior or senior level course. The course includes a wide range of student abilities and incorporates study of the interface between science, the humanities, and society.

Methods of Science was designed to fit the needs of students who needed some science after biology but for whom a chemistry/physics sequence did not seem appropriate. We had a course for lower ability students called "Energy" but it did not meet the needs of the brighter students--it did not challenge them. We felt strongly that this new course, as well as our others, must reflect that science is something one does, not just read about or listen to someone describe.

Teaching for over 10 years has allowed me to watch students while trying to understand their sources of difficulty. Several workshops dealing with Piaget and the application of educational psychology to the design of curriculum have given me considerable insight into adolescents and how they make up explanations of natural phenomena. Another source of inspiration has been my own reading program of professional journals, course books, and other related materials. Conversations with some practicing nuclear physicists also shaped my ideas, curriculum, and insight into needs.

One of the delights of an independent school is that needs can be responded to immediately. I was hired by Williston Northampton School and, after several discussions with the department head, John Gow, it was decided that I would plan and teach the new course. Mr. Gow and I discussed the needs of the class, the population for which it was intended and some basic philosophy and methodology. After jointly planning the first few days of the course, the rest of the course evolved over the summer and, to some extent, during the year as student interests were used in selection of specific topics being covered.

John Gow's suggestions about methods, his comments when he visited the class, and his generally supportative attitude were powerful influences in designing the course content and methodology. I was also allowed considerable freedom. My husband, John, a theoretical nuclear physicst, provided his knowledge of science and sources of information as well as his own philosophy of science and learning.

As we wrestled with the need for the course we were making decisions about methods of instruction to be used. We wanted active student involvement with both the materials and the methods used in teaching. As the course was a new one and inquiry was the method, I often asked students the use or value to them of some of the work done. Their considered responses made the course their course as well as mine. Scie   involves an active consideration of variables, decision making, and action. For our course to be science, students had to be actively involved with the process, not merely passive listeners.

The administration indicated their support by providing the opportunity for me to work and by allowing for the creative thoughts of myself and Mr. Gow to bear fruit. Our administration is one that encourages professional response by expecting it. Without that support our task would have been difficult.

An inservice program given in the school system where I worked suggested the possibility of developmental (Piagetian) issues being involved in problems with students. At the same time, I was taking a refresher in educational psychology at Mount Holyoke College and became interested in the results of how our students scored on a group of tests designed to measure students' ability to think on a concrete, transitional, or formal level. As I tested the students on these problems, I noted a strong correlation between their developmental level and their degree of difficulty with the concepts I had identified as trouble makers. I became convinced that I could offer information to students in more meaningful ways.

In a series of workshops using the Karplus **Development of Reasoning** materials I found the Learning Cycle to be a useful model to follow. The group at the University of Massachusetts then received a grant from the NSF to offer a second series of workshops, a full year program, in the application of the learning cycle and microcounseling techniques as well as synectics and lateral thinking. I eagerly attended that full series of workshops.

The next project I worked on was another NSF grant, again at UMASS. This time, as one of the staff, I worked with science teachers from all over New England designing curricula in the sciences using these developmental techniques and understandings. I feel that what I learned as a participant in these workshops was instrumental in designing my cou es. Mr. Gow attended the last workshop, Methods of Science, and I found that quite supportive. Now, the grant money is gone and there is no further workshop series. However, I am in a doctoral program at the University and will be pursuing many of the same ideas in my coursework.

OUR PROGRAM

The purpose of science education is not to ignore science to the point where it all becomes social studies. I structure the course to show where, how, and why science seems to be in conflict with societal values. While I do feel that social issues result from the application of science, I am very much opposed to the idea that understanding of how the natural world functions should take a back seat to social issues. A scientist does not need to be a humanist, but they are citizens and must be aware of the implications of science. I think the important issue here is that the vast majority of science students in high school will never go into science as a career--the last numbers I saw were that two percent of the population earns its money doing science. I see science education as doing two things: presenting the methods of science as ways to identify and attack problems or issues and presenting science facts that can benefit or interest the individual.

Students need to know that they can think so they will be willing to do so. They need to practice these skills so they can examine the ideas of someone else rather than blindly accepting from whatever source shouts the loudest. Science says examine the facts, look at the evidence, then decide what explanation best fits. This is more than science, it is the essence of education.

I have never thought of myself as having science students; I have students in a science class. I don't see science students or English students, I see a group of minds before me - minds that will be affected by many things in their environments. I see a need and value for all students to be exposed to the ideas of science -- experimenting, reproducing, learning falsifiability, trying techniques--if only to gain an appreciation for those things. I see learning as science and I want students to see what they can learn just because knowing things is a good feeling and being able to use the methods of science is to their own benefit. They should learn the methods of science and how they compare to those methods used in the humanities. They should learn about the universe and about where science may directly affect their lives; how science and politics or society go together. Above all, they should learn to identify, attack, and solve problems relying on their own ability to think and to know when and how to find help.

In general, our students are of high academic ability but somewhat anxious about mathematics or simply not oriented toward mathematics or science as a career. Several students have been on honors status but most are not. Last year, with 19 students, Methods and Applications was a large class for our school. Our students range from middle to upper middle class socioeconomic levels and their attitude ranges from enthusiastic about school to "I don't like it but I have to be here." This year we have two small sections of 10 and 12 each with a wide range of abilities. As a result, we have had to modify our materials and strategies of last year. As our program is continually evolving anyway, this was not a major problem.

I think "issue-centered" is an appropriate description of our program. Each issue presents its own problems as questions arise and the students perceive the scope of the issue. Flexibility is built into the plan allowing student interests to guide a full quarter's subject material. In our discussions about benefit/risk in general and in energy, ecology, and genetics specifically, value, ethical, and moral issues are raised. At no time are we looking for a "right" answer. The aim is to consider all of the ramifications of the problems before an individual decision is made. Then, the ability to back an opinion with facts should be the deciding factor. Disagreement is frequent and recognized as a value.

Science and how it works as a human enterprise is really the central focus--how we can use science to serve the needs of humankind through application and technology is a secondary focus of our program. While I do see it is useful for a science class to deal with social issues--especially for this class--I do not wish to denigrate science to a back seat. Science is learning about how the world and the universe work. This knowledge may serve the needs of man, but I do not approach learning science in this simplistic fashion. Scientists do science because they need to know; much in the same way a composer composes a work of music.

But, knowledge of science and how it works can be applied. Two examples of using knowledge in social decision making that come to mind immediately involve genetics and power. I use the "Nuclear Power Dilemma" simulation developed by Chet Corkum at Deerfield Academy. This simulation requires that students know about power and radiation so, guest speakers are invited. This year we had a radiologist, a physicist, a power company nuclear power information expert, and an anti-nuclear power organization representative as well as an alternative energy source dealer. Students take the role of experts, congressmen, and attorneys while economics, science, and political realities all come into play. The genetics unit focuses on genetic counseling with students studying illnesses which are genetically inherited. Students learn about prognoses, frequency, cost and the methods used by counselors and the possible outcomes of their findings. They then role-play legislators and design laws governing genetic counseling, funding, and outcomes.

I think the use of local conservation issues, political structures, and businesses give proof to the fact that the course is relevant to our community. Since our students are mostly boarders and come from distant locales, too much tying to local specifics is not productive and we emphasize that mechanisms, methods, and concepts are useful as they are transferable to new locales. We also use simulations to deal with the benefit/risk concept as applied to energy sources and genetic counseling. I feel this understanding of the interface of science with values and politics is important.

Students are encouraged to examine their own abilities with an emphasis on their strengths and thinking processes. Part of the course deals with conservation related issues and so, thereby, relates their skills directly to environmental problems. It is the belief of the department that all students will have their lives influenced by science, so, even if they are not going into science in college, we feel that a knowledge of methods and practices is vital to citizenship education and science literacy. With the exception of the cosmology unit, all topics are introduced and covered in such a way as to relate to current needs and address the technology/society interface.

We have time to cover many topics since the course meets five days a week with two classes of 40 minutes, two of 45 and one of 60 minutes for the full year. During this time the class functions as a group as I feel that societal issues are best discussed this way. I also believe Dewey and

Piaget that student-student interaction is a very important method of learning, especially in problem solving situations. When I present a set of information on stars and then ask the students to devise a scheme for the life cycle of a star, they need to bounce ideas off each other to stretch their thinking, creativity, and problem solving abilities. Individualization on assignments comes about as I tailor the topics and references with which a student deals.

Every topic involves group or pair discussion, problem identification, and problem solving as well. Often a pair is asked to meet with another pair to form a consensus. Except for tests and two research papers, projects always are done in pairs and small groups. Students are encouraged to help each other by suggesting sources and sharing knowledge, ideas, and abilities.

Any time it is possible, topics are introduced by presenting opportunities to observe and discuss situations before terminology is presented. The learning cycle model developed by Robert Karplus allows students to explore a phenomenon and develop concrete understandings before abstract theory is presented.

1981-82 Topics listed in order of their coverage

First Semester

Is there life on the desk? How could you prove your answer?
Viking tests - how done, what biology they depend on
Drake's equation on the possibility of life, intelligent life, in space
Means and difficulties in contacting extraterrestrial life forms
Astronomy - what was known, current frontiers, radio astronomy
Up to data - via NASA - information on planets
Stellar life history, spectra, Doppler effect
Cosmology - difficulties in studying, current theories
Origin of earth
Paleogeology,, plate tectonics; rock, rock formation, type, use of, cycle

Second Semester

Benefit/Risk - interface between science and technology and the political citizen.
Automobiles - benefits and risks in cost of highways, accidents, jobs, etc.
Radiation and energy production
Simulation of Three Mile Island Hearings
ESP - Sagan on hoaxes - Rhine's work
Experimental technique - variables, control, etc.
Genetic advances, genetics counseling - benefits and risks
Ecology - Marine biology, mariculture, protection of estuaries

For the 1982-83 school year, I added a unit aimed at increasing the students understanding of the similarities between the way a scientist works and the way someone works in the humanities. I stressed the contrast with the introduction of the experimental technique and the concept of falsifiability. The Karplus learning cycle model is followed in the design of this of most units. This model provides a concrete base for initial theory to be presented and is the beginnings of a teaching rationale. In this model, students first do some activity that focuses their attention on a particular phenomenon. Then they have a chance to manipulate and see what happens, relating their findings to the concepts and vocabulary being introduced. The final step is concept application. After trying to explain how a ficticious planet came to have its current geography, history, and terminology; and hearing about plate tectonics and evidence for it, students then explain the geography of specific areas of the world in terms of what had to be going on tectonically.

Activities are designed to bolster student self-confidence, to provide tools with which a problem can be approached so that solution and understanding are possible. Students need to build confidence and skills to do things and to feel the satisfaction of "doing it myself."

Our content shifts from time to time as specific subjects reflect student concerns. Some things, however, remain constant: how a scientist functions, the nature of science, methods and tools of science, and experimental technique.

During the fourth quarter of the year students select all the topics to be studied. They reflect on and evaluate my methods and I respond to their evaluations. Students have a powerful role in providing me feed-back on my methods and topics. I feel there are many basic skills they need to practice; public speaking, research, expository writing, text use, group management, and social interaction. Some of these they don't like to do but I insist on all of them from time to time. I insist that they think, a task some find not so easy. Perhaps many of them have had regurgitation lessons for too long.

I cannot give specific data as to the effect of this course on the future of the students. My aim has not and never will be to produce a course to serve a program outside the needs of the students. I want to help them discover the wonders of the world and their own minds, not submit a winning entry in a contest although I would, of course, help a student so inclined. As to the school in general, I feel we stack up to the line in terms of achievement. As an independent school, a college prep school in most respects, that most of our students go on to college is a given not subject to meaningful interpretation. Our program is too new to know what may happen in the future.

While Williston Northampton requires two years of science--one a freshman or sophmore course, the other a junior/senior course-- most students take three sciences and many take four. In class, students are listening, talking, doing, thinking-- if only you could see this. Activity is always varied and really difficult to describe in any other fashion. Students develop simulations by researching basic facts, analyzing and developing particpant roles and organizing roles. They then take on roles and conduct the events, hearings, or activities. They are active in all aspects of learning, planning, and conducting.

While simulations are fine, I want my class to be the real thing. So, I am trying to apply the findings of educational psychology to the way I plan my classes. I apply Piaget as seen by Karplus to the actual running of the class. I use ideas from Gordon and Synectics, from Bob Samples on creativity, and from do Bono's **Laterial Thinking**. I try to apply all theories and ideas that make sense to me. I also try to have students do science instead of merely discussing the so-called scientific method and then doing cook book operations all year.

I don't want to offer a science course to teach the scientific method and then procede to have the students follow cookbooks leading to the one "right" answer. This is not teaching science! I encourage discovery by offering labs where students are not just duplicating the book but where they identify their own problems and try to find out answers. Students use experimental techniques, gathering data in meaningful ways.

While most books always have a right answer and the students try to get it--and that is all right for teaching skills--I'd rather say "here's some equipment, use it to find out what materials can pass through a membrane and affect a cell." Doing that makes more sense to me than giving kids everything all spelled out so they don't have to think about what they are doing. Following a recipe and getting crepe suzettes may be tasty but it isn't science. And, following a recipe and getting a beaker full of smelly liquid is neither tasty nor science. Technique yes but science, no. Thinking and hypothesizing are more important to me and my students then concrete results. While materials, recipes and products are not terribly important, good inquiry is. The process of thinking and applying the methods of science are not tied to a specific set of apparatus or outcomes but whatever is available or happens.

Materials are stored in more or less standard ways but students are told what is available and warned about safety. They get their own materials, work, and, shortly before class ends, they put things away. We use materials from physics, chemistry, and biology as well as earth science and students have access to whatever is appropriate to the problem they are investigating. We use the library a lot as well as microscopes, spectroscopes, rock samples, astronomical models, fossil models, and printed materials. The never-ending source of nontraditional materials such as speakers and pamphlets is what really makes a difference.

RESOURCES

In addition to issues of **The Science Teacher**, **The American Biology Teacher**, and **Science '83**, newspapers, **Nova** and other television series on science and nature, I have used the following as sources: **The Search for Life on Mars**, Holt, Rinehart and Winston, N.Y. 1980; **Cosmos, Earth and Man**, Yale University Press, 1978; **Cosmos.** Random House, 1980; **Broca's Brain**. Ballentine, 1979; **The Dragons of Eden**, Random House, 1977; **Murmurs of Earth**, Random House, 1978; **Quantum Physics: The Cosmic Code**, Thompson, **Astronomy: Fundamentals and Frontiers**, John Wiley and Sons, Inc., 1977.

Some of these materials just give me basic background information to flush out what is available to students as they research. Some of the books are on reserve for student research while others form the basis for occasional lectures. If I were to truly list all of the books I consult for information, diagrams and data, I could fill at least three or four pages. What is important is the constant effort to keep current in the fields with which I work.

Teachers need to take part in workshops as another way of staying current. I took one with my department head last year and now the workshop group has a reunion planned. Obviously, we all felt it a positive and useful experience. I am taking a course now on creativity in curriculum development which provides me with techniques to benefit me and the students. So far, students like the methods of our class.

To help keep students current I use video tapes so students can see programs that were not available to them, I use outside speakers to present points of view that I do not know and we discuss creative processes, and society/conservation/industry issues. Speakers present their points of view strongly and student reaction is obvious. In the case of nuclear energy, the pro-and anti- people come in to lecture, generally to the entire class, and then return to help each side prepare testimony for a very realistic simulation.

Students have some say in the topics covered as well and we use current magazines and newspapers as ways of responding to the talents and abilities of each class. These sources also keep the class current. The use of pamphlets and new materials help to keep all of us up to date.

EVALUATION

Except to the extent that we attempt to make students aware of their own thinking styles, personal problems are not a part of the course. And, there is only minor emphasis on classical memorization, although some is necessary to retain information needed to solve problems. Most questions involve considerable thinking. For instance, after a marine biology unit, students are presented with a situation involving a conflict of economic and environmental issues; questions which can be answered either way. Students are expected to use facts, develop analyses, make decisions and justify the process. There is not always an answer and rarely an easy one.

Microcounseling techniques are a major part of my teaching strategy. I try never to answer questions but try to make the students find their own answers. I never play Mr. Wizard although it is a tempting role and perhaps suitable for an entertainer. But I do not see entertainment as my primary role--I want to elicit, to cause students to generate ideas. I want to facilitate situations where learning can take place. I plan lessons which allow students to come up with answers and I use considerable wait time and don't jump in too quickly. Thinking takes time and I wish to provide all that is needed.

If you were to come into my classroom, I'd be seen talking to the entire class, to individuals, and to small groups at different times. I would be heard asking many questions and making few statements. Sometimes I might give a mini-lecture at the concept introduction stage. But, even in a mini-lecture of five or ten minutes I try drawing on the students' experience to make points or relate new ideas to old ones; making analogies to help make the strange familiar. Students might be using equipment of some sort to find the answers to questions or, better yet, they may be seeking several possible answers. In my class I hope you see evidence of students working together to solve a problem. They might catch a visiting expert if they are lucky.

Luck is not a f ctor in our program, though. We plan for innovation and stimulation and changing methods is the best way I know of to avoid stagnation. The best teachers I know--the ones the students tell me are the best--are the ones that do not slavishly save their lesson plans from one year to the next. I sometimes think that the best way to avoid negative changes is to change teaching assignments every other year.

I read lots of good magazines such as **Science '83** and **Discovery** watch **NOVA, The Body in Question,** or **Life on Earth** and remember the wonder of it all and try to project that excitement. I can't really be excited about the same stuff year after year unless I change my methods, approaches, or knowledge. The kids can sense a dull approach.

I rarely use the same mater... in the same way more than two years in succession. This is because I become too aware of all the problems that the students could encounter and smooth the way for them. I need a new situation for the students and myself so that we can all feel the quest, the search, the lack of knowledge. If I knew all of the answers ahead of time it would not be science. If the students come to me for the right answer, the way it should happen, I know that I have done a poor job in teaching them how science works.

Although I am willing to share ideas with others, I feel that the prime benefit of such sharing is to generate ideas that are new; a new method, a new way to use something. Stagnation is death to science and death to learning. A teacher must learn new things and I make no secret of the fact that I take courses and read books and try to learn new things or that I don't know the answer to a question.

We talked about helium this year and the students were intrigued by the idea of a future with no helium baloons if the current supply runs out. They asked me where we got helium and I didn't know. I did find out the major source was a cave in Texas. It is a neat thing to not know and then to find out. Sometimes I ask the student to find out the answer. It depends on whether I can provide correct resources for I do not like to frustrate this kind of search.

Since the start of the program, units have been changed; sometimes in response to the students' abilities and sometimes in response to new ideas I get from reading and conversations. In this course I am unhampered with the need to produce a student who can score well on a particular exam and I have the pleasure of exploring with questioning minds. I fear that the Educational Testing Service and similar exams agencies do not test the skills I try to engender, except perhaps for sections on analytical thinking, and there, only in part.

Self-evaluation plays a part in many grades or projects with an emphasis on the formation of questions and reasoning out a situation by applying facts to justify answers. Improvement in the ability to base a decision on facts, to think it through, is always more important than a mere "yes" or "no." I really want to include more self-evaluation for students as I feel that self-evaluation should be a major goal of education.

Students also are evaluated carefully by tests, quizes, lab reports, oral and written reports, homework assignments, term projects, classroom attitudes, and group work. I want to know how much a student knows. If I compare dissimilar ideas, looking for similarities and differences, then I may understand the ideas. If you can tell me how the biography of a star would be written and what chapters would be the most explosive, you know something of the life history of a star. If you can analyze a conservation issue and detail both the ecological and the economic factors, then you are telling me you can deal with the concepts.

Teachers also are expected to self-evaluate as the school requires some form of self-evaluation from every teacher. The means may vary from person to person and include input from students on teacher evaluation forms and teacher self-evaluation sheets. We are evaluated on our participation in professional organizations and college courses or workshops as well.

If I were to evaluate my program, I guess I'd like to look into the future and see how student attitudes have fared. Do students feel a healthy respect for science or are they awed and intimidated? Do they attack problems with a sense of confidence? Do they look critically at solutions they are given? Because this course is designed primarily for students who will not major in a science field a career follow-up really makes no sense but, it would still be interesting.

The philosophy of the head master and the school centers on the wholistic education of the students as persons functioning in society. Our school really allows teachers to function through giving them a great deal of freedom in course planning and curriculum design and my department head is supportive and helpful. I know the school is concerned with education and I know they hear about the course from students. I do the job they expect. Having taught several years in a public school where the role of the administrator affected my classroom a great deal, I am delighted to be treated as a responsible professional. They expect me to care about the education of the student as a whole person--not as a science student alone--and I do it.

Our administrators have supported this program by letting me do what ever I feel needs to be done and which I can justify. Basically we operate on a feeling of trust. I also am encouragaed and supported to attend conferences with the school helping financially, usually totally.

While our goals are not changing, topics used to illustrate or as examples may. I may also shift the use of techniques around as I feel a stagnant course is no fun. As the goals are always the same, so are the behaviors and attitudes and concepts I expect from students. My use of role playing, analogies, labs, activities, visitors, materials, and day-to-day presentations will vary as new ideas suggest themselves or as student needs change.

Since, as a boarding school, my community is the students, not only does our program respond to the community, we are the community. I listen a lot. I want to learn more science and more techniques and then try them out to see what works. There is no text that covers what I'd like to cover but I almost am glad about that. I do think that teachers and students sometimes feel safer with a text. Fewer decisions must be made, fewer plans must be laid; it is easier to describe what you do. Personally, I like the idea of hunting up information or going with a new finding in the newspapers. That keeps me and the students up to date. It also impresses them with the changing nature of our picture of how the world functions and the tentative nature of science. That is part of my message about what science is and how it works.

The only changes that would materially affect the planning of the course would be to increase my understanding and ability to apply educational psychology. I want changes which enhance our success. For that reason I am taking graduate courses at the University of Massachusetts. I also read and go to lectures whenever possible, increasing my knowledge of what is going on in natural science. These changes improve me and my teaching because they make me more knowledgeable. I have to know something very well in order to make it really understandable and accessable to all students. How can I put this so they will see it? How can I give them the background for the concept to make sense? How can I create a proper learning environment?

If you really wanted the program to fail; lecture every day, get a text and stick to it, give only short answer exams, and have all labs in a cookbook style. Lectures keep the kids quiet and give a funny sense of security; they encourage dependence on the teacher while I want students dependent on themselves. As the program evolves I hope topics covered will reflect current issues and the relation of science to society. I want students to gain an understanding of the science issues under discussion. I'd like to see the day when nuclear power is not important to the kids or when they can deal with conservation more rationally. I really enjoy this class where it is fun to think. Even I as the teacher have to think in this course. I find it nice to remember that I can. I have taken several of my ideas to conferences and I think that those teachers have used some of them. The approach is important to make kids think and prove to them that they can. Teachers tell me the units work and the philosophy makes sense.

If I wanted to start this program in another school, I would provide the outline and fill it in with specifics that match the situations. The topics covered are not too important in themselves, it is how they are treated. I would read about Snyectics, Lateral Thinking, perhaps read a book by Robert Samples. Celebrating the mind and allowing students to use theirs would be my goal. I would provide inservice on the Karplus Science Teaching and the **Development of Reasoning** material. I would tell teachers to take a chance, let the kids take part. Don't try to tell them everything fo[illegible] remember best what they find out for themselves. It is really mo[illegible] attitude on the part of the teacher to seek things out, that way yo[illegible] model the behavior you are asking from the kids.

I am an active member of **NSTA** and the state affiliate **MAST** conferences and publications are important to me. Conferences and journals both give me a chance to share what I know and to learn new methods and facts about science I am also a member of NABT and find the **American Biology Teacher** useful, though more so in my biology classes than in Methods. I did use one article from **ABT** on scientific theory in methods this year. Students found it useful and clear and on a level they could read.

I read the **Science Teacher** and often incorporate items from it in my class. The free and inexpensive colum is especially useful for the Methods of Science course as it offers materials that I get into our library for student use. I am a firm believer in professional meeting attendance and I go whenever possible. I usually present a program and then attend all the sessions appropriate to my interests. Even if I do not use a method from the conference itself, the creative boost I get is great and I enhance my own skills of presenting to my peers.

I would like to formally acknowledge the help and support that John Gow has given me in designing and implementing the course. His suggestions, his assistance, and his supportive attitude have been most important to the success of the course. I would also like to acknoweldge the support and knowleuge given to me by my husband, John Durso. When you are teaching a course that deals with the philosophy of science, it is nice to have a

theoretical physicist with whom to discuss things. Conversations with his colleagues this summer added new dimensi ns to the way the course was offered this year as well.

One resource that I used in planning the course has not been mentioned--that is the inspiration of Elliot and Rose Blaustein, long time friends and highly esteemed teachers. Their work in education including books, projects, and programs they developed for the New York City system and its parts, has really been part of my whole approach to science education. Without all the course work I took to get to my own understanding, they have managed to teach science as it should be taught and have inspired many other teachers to think of science as a verb; a thing to do and to think about and to get involved in. They did it naturally, because they saw it as the right way to do things. They are super teachers and marvelous models.

Chapter 7: Problem Solving In Physical Science

By

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Seckman Junior High, about 30 miles south of St. Louis, is in a 100 square mile suburban school district with a population of 50,000. Mainly a bedroom community of commuters and dubbed the "trailer capitol" of the world by the utility company, the district contains several small factories making such things as purses, sanitary belts, and beer cans. A few dairy farms are left as well.

About 50% of the families are lower middle income or below the poverty line, 45% are middle income, including the farmers, and 5% are professionals. The community is growing and is trying to attract more businesses to furnish employment and increased revenue.

Nine-year old Seckman Junior High, tucked in the valley between two Ozark hill ridges, is nearly isolated when it snows. Twice the faculty and students have been trapped all night in an unexpected snowfall when the school bus drivers were not able to drive the narrow, twisting, hilly roads to reach us. Springtime, though, finds us with fairyland vistas of dogwoods and redbud.

We have 760 students in grades 7, 8 and 9. The staff of 35 teachers, two counselors, principal and assistant principal, part-time nurse, five cooks and four janitors work in a one-story building about 400 feet by 150 feet with 29 classrooms, a library, band and choir rooms, and a gym and cafeteria. Our yearly science budget is $700 for five teachers, divided equally, and that includes our paper supplies. The last two years at Open House parents have expressed surprise at seeing only tables and chairs and not the usual lab furniture they were used to during their high school days.

My classroom is a square, approximately 30 feet on a side. The air conditioning and heating have never worked in nine years and it gets as hot as 98 degrees in September and May and 56 degrees in winter. After the Administration spent a fortune trying to get the heating/cooling plant to work properly, the latest engineers found my room had never been connected to the heating or cooling pipes in all the nine years. Our plain science labs each contain worn, formica-topped tables that seat two, plastic chairs that are becoming dangerously brittle, and one small demonstration desk with no facilities such as gas. The science rooms have but one sink each. Our cabinets were built by me and the janitor and we have no animal rooms or green house. The physical science room has a closet for a storeroom while Biology and Earth Science have small storage rooms.

In the past ten years, with more middle class families moving into Jefferson county from St. Louis, the community attitude toward education is more expansive and appreciative. No longer is the attitude so prevalent that students are in school only because the law requires it. Twenty-five years ago when we moved into the community to do private research I, particularly, concealed the fact that I had a college degree until I had the confidence of the community. They were highly suspicious of "educated people".

Before I was asked 18 years ago by the principal to come in and substitute, my husband, a pharmacist, and I, with my pre-med degree and hospital experience, had our own research laboratory in the basement of our home. For fifteen years we did medical research on injured birds of prey for the Conservation Commission and the National Audubon Society. We had no grants, just my husband's salary and, since I was rearing three little children, I stayed home. I had ideas, my husband had the mechancial ability, and together we invented or created our own equipment. This is the same approach I bring to my students and classes today.

Later I enrolled at Webster University to meet the state certification requirements and earned a master's degree in teaching science during that college's most productive years of teaching what was then the innovative inquiry approach. Their teaching methods, combined with my own inventiveness and creativity and encouragement of my husband, developed processes which I still use today; processes such as always striving to improve, simplify, and better. My approach is practical and hands-on. I present a problem, ask students to experiment and solve. My problems are based on the units required by our state; light, electricity, sound, magnetism, and mechanics.

When I walked into that school 18 years ago I could see that science teachers, some who seemingly had never done any experiments let alone a controlled one, were teaching strictly out of a book. They were not teaching how to make a living out of science; how to get in there and do the work. While I feel theory and facts are necessary and there is a time for all of that, I feel strongly that children have to do the work with their hands in order to really remember. They need that real experience to build on and to continue further in their work and inquiry.

Inspiration for my program came as I learned science myself. I saw hundreds of ideas in nature, books, and magazines. Past experiences in garden clubs, art, hospital and medical research, and organizations were drawn upon heavily. I talked to people of all kinds and I listened. I took courses at Webster University, Boston University, The University of Missouri, and Southeast Missouri State to learn more and improve on what I already knew. I hope never to stop learning. Why don't more colleges and universities teach science as though it is science and not a vocabulary course?

Junior High science is taught during the highly formative years of an adolescent, a strategic time for orienting students toward science either as a prospective science specialist or as an informed and literate citizen. I want to assist students in researching and resolving social issues related to energy supply and conservation; limited resources of land, water and fuel; pollution and biological, chemical, and nuclear use in war.

OUR PROGRAM

I want students to develop an awareness and understanding of the world and national, regional, and local situations in energy and science-related social problems. I wish to provide channels of communication between science experts and my students. I also want to prepare students for approaching changes in lifestyle and luxury level. As I work toward these goals I assist students in seeking mathematical facts and the best scientific information available to solve important social issues.

After visiting several International Fairs and Science Conventions I came to realize that energy; its past, present, and future needed to be taught and taught now. The oil embargo forced my ideas to fruition. With those ideas I went to Union Electric and was hired as Educational Consultant to develop a **Teacher's Resource Guide on Energy.**

Social isues are an important component of our curriculum and we have explored and solved the controversy over a landfill at court. Now we are becoming involved in the Dioxin controversy. It's the school neighborhood that is contaminated.

Eight years ago the county court secretly planned and had started to put a landfill in the hills of Antonia. The local paper leaked the news and the people called school and asked us to help fight this. The children and I practiced what we preached and set up the problem as five steps to the Scientific Method. That was in October.

No lawyer would take the case against the three judges of the county court so I acted as the people's attorney. My students became researchers and we exposed misapropriation of Federal funds. Senior citizens spent hours researching for us while I taught school. Then, all information was processed in the classroom. The children as well as the town people went with me as we filled the courtroom the three times we went. The local newspapers got behind us and, in April, the State Attorney gave us the decision, saying "Its the textbook case of where not to put a landfill." It cost us $30 while the county spent $90,000 trying to prove their case. Of course we probably paid in taxes but it proved to all that you can fight city hall and win.

The case of the landfill was excellent in teaching values and moral considerations. Can you imagine a teacher, 30 students and over 100 citizens confronting three irate, hostile judges? Our class had much to discuss.

In the field of energy we have similar discussions and debates. These center on the ethics and morals of the situation. Why should they cut off our oil? Can the poor pay their bills? Will we get our fuel? Where is the profit?

Physical Science is the formal first step in studying the unseen world as opposed to the seen world of Earth and Life sciences. Physical science is the science of all the immensely powerful invisible energies such as gravity, magnetism, electricity, light and sound, all-out mysteries of the universe. Problem identification and solving techniques dealing in these energies and how to communicate are addressed by the student in groups of two or more or by themselves.

The program is related to the student's everyday experiences. It keeps up with the accelerated pace of discoveries and its applications are in the news around us practically 24 hours a day. This leads to a tremendous impact on the culture in which we live. What we teach today may not be true tomorrow. Our content may be physical science but our focus is our environment. So, we have studied a number of locally relevant issues, places, and events.

Right now we have the Dioxin controversey and we just finished the landfill problem. We have our own energy problem in our school and we have our families' soaring bills which we wish to cut back with information about conservation. We once taught mechanics with toys and ended up at the Six Flags amusement park to test ideas on the big toys, such as roller coasters. "P.M. Magazine" then came to our classroom and televised us for national T.V. Six Flags spent $3,000 on us at the park because it was open exclusively for us to conduct experiments while all their personnel were on duty.

We get out of school at other times as well. We have 100 acres of the best fossils in the world around our homes, for the school is in Imperial Valley, reputed to be the best in the United States for fossils of certain kinds. We have won many awards for fossils of museum quality found in the septic tank field at our school and in our creek. Mastadon State Park is next to the school; a park which our children helped to obtain. But, that is another big story. We are not wealthy but we get involved up to our necks and, some would say, in over our heads.

Opportunity is given to every student to select a subject or problem which interests them. They develop and actually research this problem for two months. Experimentation follows and, then, data is collected leading to a solution. This experimentation involves the student so deeply that it has led some to careers Student contact with knowledgable persons in various fields has taught them to forget adolescent shyness and communicate through speaking and writing.

Even though I have 187 students in six classes much of the program is individualized for every student and it is self-paced everyday although this is slowly killing me. I hope the gifted are challenged, the average inspired, the slow encouraged, and the burn-outs scolded. All work at their own speed, but, I do say, "At the end of the week I want Experiment I on Light, finished or not." I want them to try to organize their time to meet that deadline. I find if I don't, some drag on for weeks what should be done in one.

The essential content of our program is experimentation, measurement, graphing, five steps of the Scientific Method, Light, Chemistry, Engineering, Electricity, Energy, and Mechanics. All are essential but some years I do more in one area and other years I do more in another field. Never do I seem to have enough time to do all I want One time I figured I could teach seven years without repeating. However, some I do repeat, as children request favorites that brothers and sisters have talked about in other years.

The first week I give the minimum of class rules and explain them. Then we discuss them. In this way I find I get general compliance because students have input and understanding. I plan the lessons, based on years of what I know they like, and introduce new ideas to try out. At times they ask, "Are we going to build windmills like they did last year?" "No," I answer, "this year I thought we would try Eifel Towers since we haven't tried that in seven years." Last time most of the students' efforts resulted in objects that resembled space rockets.

Every Monday I give them their past week's grade. One time for fun I gave the highest grade the seat furthest removed from me. They vie for that now and it resulted in seating from highest to lowest every week with the lowest being "Teacher's Pet" for the week. "Teacher's Pet" is the desk next to mine and that person helps pass out papers and assignments. You would be surprised how some switch around.

Each week is very different but I will describe one past week as an example. We started the unit on Light with the first experiment being measuring light intensity and illustrating the inverse square law. On Monday I put directions on the blackboard on how to make an optical bench for only thirty-five cents. The students follow directions and watch and learn from each other while making viewing cards, scales and grids to read, and a home-made flashlight from two batteries, two wires and a small ligl bulb. The cards, scale card and grid are placed on clothes pins with mas ng tape and the clothes pins clamp on the meter sticks. Now we have optical bench. On Wednesday we discussed the problem of measuring th ead of light and illustrating the inverse square law. For research th ooked up the inverse square law in encyclopedias and copied it down. W discussed how complex it sounded and how it would unravel and become relevant when we did the experiment. Some finished making the charts we were going to use at that point and others got started setting up their apparatus.

On Thursday everyone was ready to experiment. Flashlights were readied and then the overhead lights were turned off. They were able to obtain figures for the spread of light on the grid and obtain the pattern of squares as light spread out. By using an old photometer we can obtain the intensity as well. On Friday they completed the graphs that they made from their charts and discussed the good and bad from the experiment. They also discussed what they understood or didn't, wrote conclusions, and handed it in for a final grade. We use a variety of texts designed for junior high and a number of units from the Elementary Science Study (ESS) as well.

We also use some computer software although only the math department has computers. This year we've purchased software for microcomputers to use in Science. The only way we'll have a computer in science is to use our own private ones since the school can t afford many. We use filmstrips, films, filmloo ion's Club donate the projector to me) and many outside speakers. Our films illustrate the scientific method or definitely refer to a unit or subject we are studying. Our school belongs to "Cooperating School Districts" and we receive our instructional films that way. We also use Search for Solutions and I use speakers from utilities, businesses, and groups who refer to the subject or general careers.

I begin the year in August by getting acquainted with the students and a discussion of class objectives for the year. As a group, we generate class "civilization" rules. Developed with student input and understanding, they see why certain rules are established. I give a weekly assignment of a photograph to be found in a magazine or newspaper. The assignment i based on a scavenger hunt. The student never knows where they can find it assignment. They must find pictures that show a particular concept, make observations, and provide a written description of the concept. It is amazing how this ches students to observe.

A year's schedule is posted on the wall so they can look ahead if they so desire. During September I review mathematical concepts useful for that year. These range from averag to standard deviation and includes a review of graphing. I start p with fun graphs and progress to the "real thing". At this point I a review how to do research themes for a year's continuous work. I help them to pick top s that will interest them nd sh them how to use library skills.

They state their research theme in September and actual research begins. Although research time is allowed on certain class days, the experimental part is expected to be done around December or January and a finished report is due March first. In the Fall we also study measurement with students building their own balance scale from scratch. They take great pride in their engineering and most of them keep the scales for years. Measurements are basic and important to every student, from the one who aspires to become an engineer to the ones who want to have their curtains hung straight.

Later, we study light and do many experiments, ending with the one they all enjoy--taking and developing "real pictures" with a pinhole camera made from an oatmeal box. Around December I usually introduce the study of surface tension, using an adaptation of "**Kitchen Physics**" an **ESS** unit by McGraw Hill. This is an exciting, splashy, learning experience which is very inquiry-oriented. Inquiry processes really develop during this activity and I've learned that many "elementary" activities are easily modified for 9th grade. One of these I've modified is the ESS unit, **Batteries and Bulbs** which leads to a unit developed by the Edison Electric Institute, **Electricity and me.** Investigations lead us directly into the current Energy Problems. This unit is timely because the impact of weather and high utility bills is making students listen, desire to understand, and make decisions. Career speakers and speakers from utilities are especially helpful here. We also do all kind of experiments from **Energy and Man's Environment** including collages, posters, windmill building, recycling paper and motors. I also ask students to write themes on various energy concepts and issues. I like any teaching unit to be multi-faceted and include community relevance.

In the spring I begin a Chemistry unit. More able students are introduced to **IPS** and the others do simple experiments from **Gases and Airs** (another ESS unit). This past year I featured nuclear experiments. After chemistry comes mechanics, using toys I developed in an experimental course last year for Dr. Carolyn Summers of Houston University. Students gain an excellent understanding of inertia, momentum, and potential and kinetic energy from these toys. Drafting and pre-graphics engineering, including building bridges of their own design with matchsticks and glue bring the students to the first week of June and final evaluations.

All my science units are distinct entities with separate units allowing students to make up work without getting too far behind in their other units and grades. I do anything I can think of to teach better, to handle students who have no self-discipline and challenge those who are fast. I also want to help the handicapped and develop patience for those who need help balancing a scale and can't seem to retain the skill. Resourcefulness, along with being able to give of yourself, perhaps, is the best strategy.

I spend most of my day making equipment, listening to students, helping them investigate the experiment, and discussing the theory behind the experiment. I also talk with students about careers and opportunities. As seems to be the case in an activity-centered class I am always cleaning up, loving the work, or complaining about it. I provide opportunities for daily evaluation.

It is difficult to grade 187 sp[illegible]s and get them back as fast as I can but I feel it must be done. A[illegible], I am constantly figuring out new ways to do an experiment [illegible] improve an old one.

If I wanted my program to fail, I would go back to the textbook and forget about individuals and relevance. We may be forced to stop some of our activity, an action that might harm our program as well. In the last two months any environmental study by the children has been drastically curtailed because, only three miles away, we have discovered the families living around the school are living on contaminated ground--earth contaminated with Dioxin, a toxic chemical used in the manufacture of chlorinated phenols. This chemical has now appeared in the head waters of the creek that flows through our campus, making outdoor studies impractical at this time. Open hearings show the EPA being bewildered and uncertain as to what to do; just as we are. The community has requested that we take part as scientists in helping solve this puzzle.

In addition to our polluted creek, we have a tiny observatory, built for High School use but placed on our campus where there is little light pollution. However it was too far for them to come and it fell into disuse. Two of our earth-science teachers are developing materials to use with the observatory. We are all looking forward to that.

I have lots of home-made gadgets and pictures, mostly made by students. I run an investigation laboratory where even the negative aspects of our room and situation can be useful. When I mentioned the heating and cooling problem built in with our room, it inspired one student to do an energy audit on our building. His work with the Administration, School Board, and local utility led to a report on his work, which won a National Energy Contest, including a trip to Washington, D.C. for himself and his teacher.

I also use our home, a Wildflower and Wildlife Sanctuary in Antonia, Missouri only two miles from school. These resources of nature, such as small waterfalls in my own back yard, are great.

One of our gadgets is a home-made, bicycle wheel centrifuge that works very well. Plastic containers that used to hold toothbrushes are wired to the spokes and small, one-ounce bottles donated by the drug store fit exactly into the plast[illegible] containers. It works as well as an expensive centrifuge and [illegible] is very visible.

To buil[illegible] [illegible]alance, parents and students good at shop work cut over 1800 parts out of scrap plywoo[illegible] [illegible] masonite. Each student got nine parts with which to engineer his scale. They keep their scales in a shoe box and take it home at the end of year.

Each class has a locked, home-made cabinet in which to keep their shoe boxes. This reduces theft between rooms. Materials that they need for various investigations such as clothes-pins, liquids, cards, tape, or paperclips are put on the lab desk each morning. One student is assigned to straighten the lab desk (for extra credit points), and one sweeps the floor (also for extra credit points). Any chemicals we use in Junior High are stored in a cabinet that is locked in our storeroom. I pour liquids for "Kitchen Physics", such as salt water, vinegar, or rubbing alcohol into battery jars. Any acid I need I put in labeled flasks, although at this level I try not to use anything stronger than dilute hydrochloric acid. All other equipment that we use to investigate various problems is on the lab table in front of my room or on my desk.

EVALUATION

When a students come to class they start out with an "A". If they try to work to the best of their ability they retain that A. If they spend too much time goofing off, allowing conversation to be more social than lab-oriented, their grades go down accordingly. How to act is their decision but, when they become too disturbing, then it becomes my decision and their decisions cease. They know their daily grade can go down and they have the power to make or break that grade. They have to learn to be accountable. Eighty percent love it and do well; ten percent have no strong feelings, and ten percent will never accept responsibility for what they have done. To them it will always be som one else's fault. I keep daily records of each student and compare them with those of previous years. From that I can see my own strengths and weaknesses as well as what students like the best. I give out evaluation sheets at the end of some units or at the semester's end. I keep statistical data and present quarterly lists of each class as well as individuals to counselors and administrators. Sometimes I will ask at the end of an experiment "what was good and what didn't you understand?"

I keep daily records of students, both academic and conduct. Their test grades for each unit can come from work they have already done. When something has to be brought from home students have two weeks notice and they either have it or they don't. For this they get an "A" or an "F". Grades are tied into performance.

Although lab papers have been previously graded, they are all to be in a notebook and in order. I list the contents of the lab book on one end of the blackboard so everyone has a fair chance to s[illegible] I expect. When an experiment is repeated with unknowns or when a [illegible]ent is very individualized it can count as a test as well.

Student grades are recorded when they wa[illegible] the classroom each day. I feel that fifty percent of my students p[illegible] outstanding achievement while another thirty percent perform far above average. About five to ten percent don't do well at all and are resentful that there are no set answers to copy. These students literally begin to refuse to work. While they have been used to getting by, in this program the spotlight is on their own individual work and they want to hide as it becomes more and more evident they are not doing what they should. They refuse to bring paper and pencil to take any notes of their experiments and try to break lab equipment so other students can't use it. This type of program relentlessly shows up their lack of willingness to do the work and exposes their lack of endeavor compared to other students.

SUPPORT

Our superintendent, Mr. J. Rickman, made it possible for me to attend important meetings such as an energy conference in Washington, D.C. although strong, factions in the school gave him a difficult time by implying that he would let me attend science fairs and meetings while not letting other teachers go. He faced down this criticism by pointing out that it was my students who were competing for scholarships and awards in local and international science fairs and I was the Director of the Missouri Junior Academy of Science and needed to be there or that I was State Director of National Energy Education Day. Besides that, he pointed out the good press it brought to our school [illegible] principal, C. Nettles, and assistant principal, L. Stacy, have [illegible] been support[illegible]. They have always backed me.

Parents are supportive and help me make [illegible] and they also speak to the class. I sometimes have workshop at night so parents will know how to help their children with science projects. Parents also go with me on Saturday field trips and furnish transportation.

My administrators encourage me because if I do well it is also good for them. They try hard to get supplies I need although we're not always successful because there is only so much money. The administration supports me in opinions, ideas, and resources; they really do back me up. The Superintendent lets me go to important meetings and always provides a substitute. I don't over-do this as I feel a teacher should be in the classroom. And, no one complains about my achievement. In fact, the school asks every year for a listing of my classes' scientific achievements to present to the school board.

I have always enjoyed my principals. They have let me alone; they have had confidence in me that I was doing my best and doing what I should. They could see tangible results in the publicity that we brought to the school and the trophies and prizes the students won.

Other teachers find this approach interesting, but do not care for the work and preparation of hands-on science. My own daughter, a math teacher working with me this year teaching my three over flow classes, says science is much more interesting and fun than teaching math but also three to four times more work. Still, the other science teachers on the faculty more and more have incorporated experimental work in their lesson plans and are doing research projects also.

I get some student input on lesson planning but mainly I plan for the school year based on my previous experience combined with new ideas. Every day I evaluate how they worked and give thought to how did I do; did I make that clearer? Did I become too impatient with the goof-offs? What did I achieve? Students help with putting out and preparing lab materials and with clean up as well. In the beginning my lessons are more teacher structured. But, as students learn their roles and complete their jobs I ask them to help others and give them more responsibility. They learn more by doing this.

To keep up to date I take refresher courses, go to workshops, and read professional journals. Right now we are working on the dioxin problem in this community so I am learning all about it. Opportunities to interact with people in science are beneficial for me as well.

I would like to be the Science Supervisor (if we had one) because elementary teachers are begging for in-service workshops and I would like to help them plan but I have no released time. Now, teachers from private schools in the community come once every two weeks to my home at night for ideas and they also want me to do workshops in summer.

If I were able I would go to their classrooms and directly help them by doing small workshops at each grade. I want so much to do this and spread what I know around because I know my experiments are good. But, teaching six classes a day gives me no time to go to other schools in our district. If only we could afford a science supervisor! I feel frustrated. The Superintendent remarked one time that some teachers are so jealous of me that they would never cooperate. But something would work out; they are just insecure. I want to give and take more workshops.

When NSTA came along and recognized my work I felt a lot of personal satisfaction. I also got satisfaction for other awards like Outstanding Science Teacher of Missouri, Outstanding Science Teacher of Metropolitan St. Louis, and the Conservation Award. I also appreciated being State Director of National Energy Education Day and State Director of The Missouri Junior Academy of Science. Another reward was teaching a summer class for gifted high school students at the University of Missouri-St. Louis. I only wish the tangible rewards for teaching were as great.

In my own school, as I educate new Physical Science Teachers (who replace those who leave the field for business), I act much like I would in a teacher student-teacher relationship. Some, like my own daughter have worked with me; others have found the preparation and work exhausting, and gone back to teaching out of a textbook. They said "hands-on" was too much work and they didn't want to take that much time. When educating a new teacher, I spend about two hours a week with them going over the next week's work.

Teachers need enthusiasm as well as masking tape, paper clips, and staples. A teacher with imagination, enthusiasm, and a creative mind can do wonders. Teachers should be no different than a child who enjoys discovery and sees "newness". Teaching is as much a matter of imagery as imparting actual facts. The greatest barier of this program's success is a teacher who is "married" to a textbook and teaches pure facts without fun. What the students had fun with is what they remember through life.

The National Science Teachers Association has influenced me greatly. NSTA gave me the opportunity to discuss my role in assisting Dr. Summer on her mechanics program and telling my part in it at the Nashville regional NSTA meeting in 1981.

Students learn how to do a science experiment in five logical steps and report on it in such a way they can communicate it orally or in writing. They have been very successful at this. In my sixteen years of teaching three of my students have gone to the International Science and Engineering Fair winning third place and other prizes. I have had two winners in the Westinghouse Talent Search; six math winners in Jefferson County, Missouri Science Fair; Eighteen Missouri Junior Academy of Science winners, one who placed in WMSL Engineering, Science Symposium; 106 Scholarship winners in the St. Louis Post-Dispatch Science Fairs; and 378 trophy and blue ribbon winners at the Monsanto-Post Dispatch Science Fair. We also had a 1981 National Space Shuttle Regional Winner and, in 1981-82, two national Energy winners for Individual Research work. Four of my students have become Student Co-Directors for the State of Missouri on National Energy Education Day. One has appeared before Congress in Washington to speak on the Energy Education needed in a school curriculum.

While I was at Washington University Arthur Holly Campton, resting from his duties as chancellor, used to come over to the physics lab where I was always struggling after school. Dr. Compton always teased me about how I would set Physics back for twenty years and that he had better help me so I wouldn't blow up the world. And he with his atom! Dr. Compton and two other professors, Drs. Jauncey and Hagerow, were my mentors--they have proved necessary in the business of getting ahead. I am not a self-made achiever. My husband, A. Kemps Kirkpatrick bounced ideas back and forth with me and helped make many of my ideas practical. He continues to be an invaluable source of inspiration. William McConnell, professor at Webster University, helped me learn to formulate my ideas while teaching me using inquiry.

Eddie Davis, Senior Administrator of Community Affairs at Union Electric introduced me to the community, encouraged me to present my ideas to other schools and used my role as an Educational Consultant for Union Electric. Between us, an Energy Program was launched. Now, my oldest daughter, Vera McCullough, team teaches with me in Physical Science and is helping me improve the program by introducing microcomputers. My son Rodman, a petroleum engineer in Houston, keeps me posted on th very latest in energy for my program. My youngest, Becky Anne Kirkpatric a systems programmer/analyst informs and instructs me on the latest ics, computers, and space. My son-in-law, Carl McCullough, a med b technician, keeps me informed and in touch with medical work and gives me cast-off material that we use in our laboratory.

I wish to give special s to Dr. Charles Granger, Professor of Biology at the University of ri-St. Louis and the state chairman for the Missouri Search for Exc in Science Education. By noticing my program and nominating me as ouri State exemplar, he has allowed both me and my program to gain imp recognition.

Chapter 8: Individualized Science Investigations

By

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Sunburst, a small prairie community 120 miles north of Great Falls, Montana, 8 miles from the Canadian border, and 80 miles east of Glacier National Park has a population of only 400 people. The community's financial base rests on farming and oil and seems fairly stable. Most of the families are middle income in status. The climate ranges from warm in the summer to very cold in the winter with very little rain at any time. North Toole County High School, with grades 9-12, has 80 students, 12 teachers, 1 principal and 1 school district superintendent. The high school building was constructed in 1951. The grade school and junior high are near but in separate facilities. The atmosphere is generally academically oriented with most students involved in a number of extra-curricular activities ranging from band to athletics. Discipline problems are few. The science facility consists of an office, a classroom and a separate laboratory with an attached supply room. Tables rather than desks are used in the classroom and the lab is well equipped for a school our size. The school draws students from a large rural area.

In 1971 our Science Seminar involved considerable individual student research. Later, the program was expended to include minicours work in zoology botany, and microbiology and opportunities for seniors to tutor underclassmen. Many of the research students entered science competions such as science fairs, symposiums, and the space shuttle contest. The hands-on, individualized student research approach and emphasis continues without change. We only require Biology so this course is an elective for all students. We are considering moving to a two year science requirement, however. As a teacher, I have had almost complete freedom in developing both the facilities and the program.

Originally, a few students were doing projects on their own time. As time went by, more and more students became interested and involved. Eventually, over a two or three year period, the number of students involved became too many to handle extra-curricularily. At this point the administration was convinced of a need and added the Individualized Science Investigations course to the curriculum as an elective, giving students and teacher more in-school time to pursue their individual interests.

Original program inspiration was a result of student enthusiasm and the powerful interest and encouragement of the late Paul Schrammeck, an ex math-science teacher who was our superintendent. Student success in science competitions was an inspiration as was the realization of the need for a program combining academics with competition. We wanted a program giving gifted students a chance to do rather than just study science. We wanted to direct capable students toward scientific careers and enhance science literacy. The combined support of the administration, staff, parents and school board have been very important to the success of the program. Their contributions involved encouragement, interest, funds, time and cooperation.

While we developed a student research program we also individualized coursework in specialized areas such as botany, microbiology, zoology, math, and psychology. These minicourses accomodate student interests and needs in a small school where the curriculum and staff are limited. This approach has allowed the science curriculum to develop within the frame work of a regular school day and personnel. Professional Journals provided inspiration as well as background ideas and information for student projects. I still find **The American Biology Teacher** a particularily good journal for this purpose.

Students involved in the ISI program are made to feel special and are provided with bright and comfortable classrooms and labs. We have preserved plant and animal displays, large wall murals of a forest scenes and, in the lab, pictures of the moon grace the walls. Many living plants are placed on the tables in the classroom. Living animals such as fish, crayfish, crabs, gerbils, lizards, and a parr. "King Tut", are cared for by the students

Hot water is available for students who want hot chocolate or tea while they are working in the lab on their projects during a study period, at noon or after school. A stereo-radio purchased by the math-science club is available for those who want to listen to music while they work. A fume hood separates the classroom from the lab allowing the teacher to conduct class in the classroom and yet observe students working in the lab. Quarters are not cramped and equipment is readily accessible. It is a very useful and comfortable place in which to work.

Bulletin board displays are colorful and informative and an inspira[illegible] of the week is present. An assignment board is used and home[illegible] "in" and "out" boxes line one wall while individual bookcases filled with reference books line another wall. AV equipment, slide previewers, slide and filmstrip projectors, movie projetor, and tape recorder are present for class or student use.

Pictures, charts, skeletons, and models also are displayed in the science [illegible]. An office near the classroom is used as a storage room for important reference books and valuable pieces of equipment that need to be locked away. This area is also used as a work area for student experiements that must be conducted under very controlled conditions.

For a small school, we have managed to collect a good deal of equipment; we have a spectrophotometer, analytical balance (tolerence .0001 gram), environmental chambers, laser, photomicrography equipment (poloroid & 35 mm), medical and phase microscopes, water and soil analysis equipment, solo-learn programs in biology and chemistry, audio-visual equipment for student use, incubators, and high temperature and drying ovens. A photo developing and processing lab is available for students along with two fume hoods, millipore filtration equipment, electrophoresis equipment, geiger counter, and a refrigerator.

While some equipment such as balances and incubators are available in the lab for general use, most materials such as chemicals and glassware are kept in the sto room near the classroom. Materials are dispensed by the teacher or laboratory assistants. Dangerous chemicals are kept in a metal cabinet in the supply room. ISI students usually have access to the supply room but are not allowed to use dangerous materials from the metal cabinet or conduct dangerous experiments unless directly supervised. Clean up is the direct responsibility of students although lab aides do their share of general clean up work. At times an entire class will help with the big clean up jobs. We have an open lab policy and students are at times allowed to work in the lab on their own (evenings, week-ends) with permission as long as the work they are involved with isn't dangerous.

OUR PROGRAM

The Individual Science Inve tig ions course is basically a problem solving course where students ide tif and select problems they want to research. Participants in ividualized Science Investigations are generally of high ability alth lowe ability students are allowed to take the course if we think it t benefit them in some way. Class size is usually kept to around 10 students since it is hard for the teacher to take more than 10 students when he also has a normal class load. Students generally have an excellent attitude toward the class. It is an elective and they are there because they want to be. There is a tremendous amount of satisfaction in completing a job and doing it well. Also there is no stigma attached to the course such as "only the brains are involved in science projects." Participants usually are involved in a wide variety of other activities like student government, cheerleading, band, or athletics. We have not had any handicapped students in the program.

Students have the freedom to choose their own projects according to their interests and future needs but, when problems arise during the research experience, they must be able to adapt in order to work them out. Some of the research they choose relates to careers or current problems, such as pollution, nutrition, or energy. Students choose rese areas that interest them and after they become more knowledgeable abou these areas they may decide to ente field involving that study. Also, they may realize that they only thought they were interested in that study and may decide to pursue something else. Either way the experience is a valuable tool in directing students toward careers.

Stud ts are often able to relate their research to modern social problems which helps them decide which side or opinion they will support and why. For example, an experimental study of mutagenic agents may lead the student to a realization that food additives y be harmful to the human body. Such a realization may change a ting habits. If the decision they make involves a proble wit ramifications, it may influence how they vote.

Applications of research are always conside e terminat on of a project and many times such applications involve value judgements as well as moral and ethical considerations. For example, is it right for a farmer to use a chemical agent if a better method of insect control is available? Also, the actual involvement of animals for experimental purposes often involves ethical considerations.

Gifted students are encouraged to choose more challenging projects. Students individually meet with the supervising teacher who answers questions, asks questions, makes suggestions and g erally helps to monitor and direct the student's progress. Although their approch usually involves scientific inquiry, many modifications of how they inquire may be made along the way to reaching their goals. Students budget their own tir and plan their own approaches. Design and construction of experimental equipment, the research, the professional paper, and display materials all involve their own creative abilities, insights, and production. Certainly, this approach is scientifically valid and is a culturally acceptable and useful way of logically solving problems.

The major goal of scientific research is to benefit mankind although personal satisfaction and cooperation with other students in sharing equipment and discussing each other's work are also important aspects. Interacting with professional scientists who advise them during their research contributes to the students' skills and science liter as well.

Many different kinds of problems are explored in the ISI program, some with local and community significance and many involving the natural environment. For example, students have conducted a study of the bacterial content of community water supplies, the effect of oil spills on local flora, and a study of the parasite load in the local deer population.

Often businesses in the community may make a contribution. For example, a local elevator supplies one student with plant seeds for a botany project or a farmer supplies a student with soil samples for an agronomy study. Several projects have focused on students themselves. Two examples are a study of visual perception in grade school students and a study of nutritional habits of high school students. The problem solving process can always be improved with practice and should carry over to situations involving every day, non-scientific problems.

Although the work is individualized, interaction and cooperation between students is encouraged and sometimes necessary. Students are required to have an understanding of each other's work, so some time is spent with groups of students discussing their work. Students may at times teach each other special techniques needed to carry out their reseach. A second year ISI student may teach a first year student how to use the millipore filtration equipment or perhaps an autoclave. This interaction between students and teachers is continual while interaction between students and professional scientists occurs frequently by phone, letter and sometimes personally. Often parents are involved in some facet of the project and community members are called upon often for advice or for needed materials.

The intellectual and social growth of the student is always of utmost concern during the year with different methods being used to facilitate this process. Our open lab policy is designed to help students grow more responsible. Strategies for growth are developed according to the criteria of the teachers involved. If they don't work, new approaches and criteria are developed and old ones modified. This, too, is an ongoing process. What is taught and how it is taught are directly reflected in the philosophy of the teacher which in turn is based on his training, personality, past experiences, and interest.

Most of all, the teacher's role is that of an understanding person who will trust students and take their ideas seriously. A combination of teaching strategies is used including small group lectures and discussions, demonstrations, overseeing lab activities and individual conferences. Most of the teacher's time is spent with individual students. The teacher is the primary resource person in charge of directing the research activity of students. I avoid doing too much for the students and they assume responsibility for organizing and carrying out the research on their own.

Problem identification and solving are emphasized by placing considerable importance on experimentation. Experience in collecting and organizing information, asking the right questions, developing hypotheses, learning certain lab techniques or how to use different types of scientific equipment are vital in the process of experimenting. Graphing, statistical analyses, interpreting results, and writing a scientific paper are aspects of communication necessary for these scientific processes as well. Constructing a display, the judging experience and oral presentations also are important. Developing englfsh skills, communication skills, patience, perserverence, and budgeting time, may not seem like part of science, but they are critical to our program.

I believe the ISI program goes a long way in not only helping the student learn more about the processes of science but also in helping them gain experience in a number of other areas which will help them become better students and more successful, responsible adults. Not many other courses do this to the extent ISI does.

Students play a key role in selecting projects and carrying out experimentation. The teacher is the advisor, a resource, a facilitator. There is virtually no group lecture time and never any exams. The students proceed at their own rate and are responsible for their own work areas. In return, they have certain privileges not available to other students. They help maintain the lab and they can lose their privileges if they don't show adequate maturity and responsibility. After students have completed a project, an evaluation is made which involves the student. How much have they learned? We look at the quality of their work, their opinion on how well they did, and their own expectations.

The entire progression through the scientific method in ISI involves continual decision making on their part. They must decide when to start the experiment, what to do, who to contact for advice, what to order, where to work, and how many experimental subjects to use. When they are ready to present their projects, they make similar decisions about their written project, their oral presentations, and their displays.

If you were to visit our ISI class, you might see some students writing letters while others are going over letters they have just received from consulting scientists. A student may be making a phone call to a resource even as another student is teaching someone how to use a certain piece of equipment. Some are setting up equipment or consulting with the supervising teacher. Others may be ordering materials from a supply house or typing professional papers. Late in the course, someone may be in the woodshop constructing a display. Students also may be working on mini-courses, enhancing their content knowledge in various areas of science. Some students are usually in the library researching background information while some are collecting experimental data. When a student has all his work caught up and has little to do, he may even be doing homework from another class. Students may be using the computer for instructional purposes, for word processing, or to learn more about computers. Students also consult with other teachers for advice on certain aspects of their projects, papers, or presentations.

The course is an open-ended individualized research program where little formal teaching is used. Unit plans don't exist because each student is self-planning. We do plan for teaching specific skills as needed and our long range goals for all students are similar. Our approximate calendar of events for the year follows:

SEPTEMBER

1. Introduction to course
2. Slide program on research method and science competitions. (motivation)
3. Assign lab drawers
4. Select research project and begin to establish contacts with research scientists who may be able to advise contacts with research scientists who may be able to advise the student on certain phases of his work or provide materials.

OCTOBER

Gather information about project and begin library search.

2. Gather materials needed for research

3. Instruction on use of basic lab equipment & techniques.

NOVEMBER

1. Individual conferences.
2. Experimentation underway
3. Library search continues

DECEMBER

1. Experimentation
2. Individual conferences
3. Work on space shuttle proposals and Junior Science & Humanities Symposium presentations.

JANUARY

1. Experimentation
2. Individual conferences
3. Work on space shuttle proposals & symposium presentations.

FEBRUARY

1. Experimentation
2. Individual conferences
3. Continue working on space shuttle proposals & symposium presentations.
4. Analysis of results
5. Statistical analysis

MARCH

1. Experimentation completed
2. Construction of display
3. Individual conferences
4. Preparation of professional paper.
5. Participation in science symposium

APRIL

1. Participation in state science fair
2. Participation in school display night.

Only juniors and seniors are allowed to take ISI and then only after they have established background skills in mathematics, the physical sciences, and biology. Their projects commence with an idea and end with both ideas and a product in the form of a complete display and oral presentation of the student's work. Research takes time and the students are allowed about seven months to complete their work although two-year projects may be undertaken with teacher approval.

About 10 students per year undertake this program. The students are in class five times a week and are allowed to work when the teacher is available during study hall, his prep period or during the established ISI period which is the last period of the day. With the last period class and many optional times we have a student to teacher ratio which creates few management problems and allows students to continue their work after school without interruption. Also students may work in the lab during lunch or in the evening with permission and as supervision is available.

The gradual development and success of the program has established a certain attitude in our school. Students taking ISI are generally admired. Occasionally, however, the students involved in a program such as this are labeled "the brains" and are thought of as different. We work hard to eliminate this type of prejudice.

To attract new students the supervising teacher spends some time discussing ISI activities with underclassmen. At times ISI students may be asked to present a specialized topic to another class and also are available as tutors. A motivational slide program on student research, science competition and the International Science & Engineering Fair is presented to sophmore biology students at the end of the school year.

All biology students are required to do mini-projects of their choice and write short professional papers. This introduces them to problem solving work. Many of them begin to develop an interest in this area and wish to pursue it in the ISI program. We also have a project program for junior high students so they are often familiar with project work when they enter high school.

ISI students have certain privileges that other students don't have. For example, they have access to lab facilities after school and on weekends and a rather informal, confortable atmosphere in which to work. The "hot pot" in the lab for them to make tea or cocoa to drink while they are working and a tape deck so they can listen to music while they work are well known around school. Also, the school is small enough so that most students are aware of the awards, scholarships and trips that ISI students often win and this is certainly an incentive even though students are often reminded that these are not the most worthwhile goals of the course.

Problem solving courses are always relevant for we have many scientific and non-scientific problems that need solving to make this world a better place in which to live. You certainly don't have to be a science career oriented student to benefit from a course of this type. The course is individualized and students are often attracted because of this. There are no exams and no homework; students have a vested interest in learning and working at home.

Any materials that provide students with ideas for possible research projects or background information for project work are used. Such materials include science reference books, science texts, lab manuals, scientific journals, and popular magazines. Slide programs prepared by the teacher are used to recruit students, explain the program, and motivate student interests. These programs include sections on the scientific method, the state science fair, the Anaconda Company Scientific Achievement program, International Science and Engineering Fair, Space Shuttle Competition, Junior Science and Humanities Symposium and the Navy Science Cruise. Biotech modules are used to teach students specific skills while filmstrips enhance concepts. I find three source books very valuable. These are **Nuts and Bolts: A Guide to Science Fair Projects,** by Van Deman and McDonald. I require that students read this over. **Guidelines for High School Students on Conducting Research in the Sciences** by Lyon, and **A Handbook of Biological Investigations,** by Ambrose and Ambrose, are also quite useful.

Outside reference people are also consulted by the students with contacts made by letter, phone, and sometimes in person. On occasion students will travel to a research facility at a hospital or university to complete some phase of their experimentation that they cannot complete in the school lab.

Each year the program is e aated by the teaching team and changes are made based on past mistakes, student needs, and insights into future directions.

The program is reviewed annually by several teachers and the principal in an attempt to devise new and better techniques which may result in improvement. Modifications and changes that are deemed necessary are implemented the next school year.

Students are evaluated by the supervising teacher at the end of each semester. Since the basic approach involves problem identification and solving techniques, how well they use science methodology not only affects the outcome of their research but is reflected in their ability to make rational decisions. As they gain experience in using this approach they should become better at it and should be able tc relate it to other areas of their lives that involve problems of both scientific and non-scientific origin.

Students are evaluated by individual interviews conducted periodically to determine how well they are progressing with their work and how much they know about their projects. The final display and professional paper are evaluated by the teacher and a letter grade is given at the semester and at the end of the year. Awards at science fairs and competitions are useful in evaluation of student work as well.

The teacher self-evaluates and receives feedback from the principal and students. Student's work, displayed and presented orally, is certainly a visible and public reflection of the teacher's effectiveness in this type of program. One hundred five students have enrolled in "Individualized Science Investigations" over the ten year period of its existence, and 97.2% have completed the program. At this time 23% who completed the program have graduated from college and 8% have graduated from a technical school. Seventy-one percent of these graduates have graduated with a science or science related degree and 54% are currently active in science or science related careers. About 39% of those completing the program are currently in college and 50% of these students are pursuing science or science related study programs. In summary, approximately 70% (72 students) of those who completed the program attended post secondary schools and of these, 57% (41 students) pursued or are pursuing science careers.

More frequent evaluation sessions involving the teaching team of science and math would be helpful. A more objective measuring tool for evaluating student progress and understanding would aid us in evaluating students who do not complete projects or do not win awards.

Our average cost per pupil varies from year to year depending on the type of projects the students choose and the amount of travel required to science fairs, symposia, and competitions. The average cost per pupil lies somewhere between $100-$200 per year with travel a major expense. At times a major piece of equipment such as a photometer may have to be purchased. When major equipment such as this is purchased every effort is made to ensure that the item can be used within the program again. If equipment or facilities are needed that are beyond the financial reach of our budget or seem to have limited applications, then an attempt is made to borrow the item from a research facility or perhaps the student will travel to that facility to conduct some phase of the research. I believe the next major budgetary undertaking is a systematic, gradual replacement of old or worn expensive items. We are trying to do a little each year to prevent a major and perhaps impossible expense if they all have to be repaired or replaced at once.

The administration has provided support by helping to secure governmental and district funds to help develop the program. They also allowed the course to become part of the school curriculum even though we are a small school. By becoming involved in the instruction of the course, the administration has truly shown the interest and value they give the program. Also the administration has provided a supportive front to the school board and community; an attitude necessary if the program is going to succeed for any length of time. Last but not least, constructive criticism from administrators is a valuable aid in modifying the program, upgrading it, and preventing stagnation.

Our administration has shown support for our program in a number of ways. The original encouragement and support to develop the program came from the late Paul Schrammeck, superintendent of schools. He also helped by securing funds to remodel lab facilities and purchase major equipment via government title programs and also convinced the school board to become actively involved in supporting the program. Over the years the changing administration has continued this support. Many administrators had science backgrounds and that surely didn't hurt. One principal, Mr. Dennis Roseleip, was actively involved in the program by advising the students involved in psychology projects. Our present superintendent, Mr. Alan Ryan, teaches a physics class within the general science curriculum. By giving verbal support to our school board and our community, the administration has helped to put forth a unified front of support which is necessary if a program of this type is going to survive. It is important to the students and teacher to know the administration is behind them and will do everything they can to secure financial and moral support for the program. So far we have had little trouble in obtaining the needed funds for the ISI program and much of the credit for this goes to our administration.

The community has generally been proud of the accomplishments and awards won by the students from this program and help by voicing their suppport to the administration and school board.

The teachers have been a great help by showing interest in students' work, by giving up, on occasion, some of their class time to allow students to work on projects, by discussing projects with students, and by critiquing student work. English teachers proof read written material, the shop teacher helps students construct certain parts of the projects, math teachers help students with math and statistical interpretation and allow students to work in their designated areas when more room is needed.

Parents support their children in a number of ways. When they understand and support the committment the student has made toward the project they often become involved in the project. For example, in some cases they may help the student obtain materials or perhaps provide transportation to and from school so the student can work on their project after hours. At times they may be asked to actually help in the construction of some phase of the project. If a board has to be sawed or a piece welded they may help do that. Parents also help by accompaning their children to science fairs, giving them moral support, and showing their interest in their childrens' work; all worthy educational objectives. Perhaps such an involvement will help develop better rapport between student, parents, and teacher.

NSTA and NABT have both provided general support for student involvement in science beyond the classroom. These organizations, particularly NSTA, have helped to establish a philosophy toward animal research which has been helpful in student selection and approach to a project that involves animals. NSTA also has sponsored and supported student centered activities such as the space shuttle contest which plays an important part in our ISI program. NABT sponsors "Outstanding Biology Teacher" awards and the criteria for selecting the award often involves teacher success in working with students involved in individual projects.

Professional Journals often provide me inspiration as well as background ideas and information for student projects. The American Biology Teacher is a particularly good journal for this purpose.

Although other faculty members may not be directly involved in the ISI program they do often function in a supportive role. Our school is small enough so that students and teachers relate on a one-to-one basis. Students often discuss their projects with interested teachers and may ask the english teacher to proof read material, the math teacher for help with statistical work, or the librarian for help in locating research information. Or, they may ask the shop teacher for advice in constructing some part of the project. This interaction of departments helps the student realize that knowledge is interrelated and that his work as well as himself as an individual are important.

We do have great confidence in the ISI program. As time goes on and we learn the ins and outs, dos and don'ts of the program, it continues to develop. This development is an on-going process which should never stop although our enrollment is decreasing and this may effect some long range goals. Realistically, I do not see many great changes in the goals we have established for I believe them to be sound educational goals for better learning the processes and nature of science, developing responsibility, and establishing worthwhile life skills. We may have to modify our mini-course offerings to better meet the needs of students, however. I do realize that the goals we have set down should be scrutinized and discussed at the end of each year and if additions or modifications are necessary then changes should be made.

I do believe student interest in the course will be sustained as will administration and district support. I expect our facilities to improve with the expected addition of a greenhouse, animal careroom, and individual work area. I expect more involvement from math teachers and the counselor and I expect more diversification of projects being selected. I also believe our mini-course selection will be expanded and we will get a little better student involvement in this area.

Changing our program should increase student and teacher interest and participation if we expand the curriculum and produce a more balanced approach to student involvement. Currently, more students are involved in work in the area of biological sciences; perhaps more will become involved in other areas such as physics or math. Such changes should always serve to better meet student needs.

The program is individualized and was developed to fit the needs, facilities, and staff of North Toole County High School. To exactly duplicate this program in another school system would be both undesirable and very difficult. It would be desirable, however, to implement those aspects of the program that would be compatible with other school and science programs in an attempt to improve overall curriculum. Other teachers have visited our school to learn more about the program and we welcome this type of contact.

Communication is very important and the involved teachers should meet frequently to discuss the program. Changes should be made periodically to upgrade the program with student input considered in this process. Also periodic meetings with the administration are helpful in planning the program from a budgetary standpoint. We stick with what works but are not afraid to try new things. We find continual assessment to be important.

You must have teacher dedication and student interest if a course of this type is to succeed because it takes a great deal of effort and time. It is absolutely necessary that the teacher maintain an enthusiastic approach to the program. In another school, I would begin by conducting a motivational, instructional workshop for involved teachers. I would then follow up with a similar workshop for the students. Once the program gets off the ground motivation seems to be self perpetuating with success leading to success. I would then invite teachers, interested students, a representative from the administration and a representative from the school board to my school to view the program first hand. I would emphasize organization of facilities and course funding (major purchases could be staggered to prevent large initial outlays of money which tend to discourage administration and school board support). It is necessary that a coordinated plan be developed by all of those involved in the program so that the course progresses at a steady pace over the first few years. Often interest in specialized courses rises quickly and then fades the same way. Proper motivation, orientation and planning may prevent this from happening.

I believe the teacher should have a well rounded education in all the sciences and a strong background in math as well. ISI students work on projects in all areas of science and engineering, with all work involving statistical analysis and a working knowledge of math. The teacher should be grammatically competent and personal research experience at the undergraduate or graduate level would be useful. Students need proper advice, not only on their research but also on the written part of the course such as professional paper and presentation. The teacher also should be able to instruct students on the use of some specialized science equipment such as spectrophotometer, environmental chamber, analytical balance, and electrophoresis apparatus.

The rewards for teaching in this program are many. Satisfaction comes from watching students develop a finished product from an idea and seeing them realize the importance of the activity. I take pride in student success, particularly when it involves a lower ability student with confidence problems; such success stimulate me to continue. During competition, I enjoy meeting new people, going to new places, and learning new things. I like being involved in doing science and combining academics with competition. I also enjoy bringing academic recognition to our school.

As a result of this ISI program I and my students have won a number of awards. These include:

* NABT - Montana - Outstanding Biology Teacher (1978)
* Certificate of Honor-Westinghouse Science Talent Search
* Award for meritorius work with science students
* Eleven Science Service Commendations for student participation in the International Science and Engineering Fairs

* NSTA Certificate of Excellence in Science Teaching
* Three American Society of Microbiology Awards for Excellence in Science Teaching
* Two NSTA/NASA Space Shuttle Certificates of Recognition for student regional winners
* The Thomas Alva Edison Foundation Certificate of Recognition for Excellence in Science Teaching
* The Kodak Award for student excellence
* The Elks Distinguished Citizen award
* An Area Chamber of Commerce Certificate of Achievement
* The KSEN Radio VIP Award
* A Student Appreciation Award from our ISI students
* Not only have we had a Westinghouse Science Talent Search top winner, our ISI student have won the State Science Fair Grand Award every year since 1974 as well as thirteen special or place awards at the International Science and Engineering Fair
* Two students have won U.S. Navy Cruise Awards and three have first place scholarships from the Anaconda Company
* Six students have been awarded American Cancer Society Summer Fellowships while two have been Regional winners in the NSTA/NASA Space Shuttle Student Involvement Project
* In the past five years ten students have presented papers at the Junior Science and Humanities Symposium One of these was selected to attend the national symposium.

I would like the math teacher to become more formally involved in the program and I would like the guidance counselor to take an active part in advising students working on psychology projects. We have had this type of team involvement in the past but a turnover of staff has forced us to regroup and this process takes a while. I would also like to see more students involved in minicourse work and a little more formal approach in course organization may be beneficial. I would like to see more students involved in math and physical science projects.

I would like to express my appreciation for the help and support given by my patient wife, Maria and the inspiration provided by the late Mr. Paul Schrammech. I also have been aided considerably by Dennis Roseleip, Larry Moye, Robert Ross, Alan Ryan, Mary Moffatt, and all the North Toole County High School Staff and School Board of Trustees. (For more details on North Toole County High School and the Individualized Science Investigative Program, see the NSTA Search for Excellence in Science Education Monograph, **Centers of Excellence:** Portroyals of Six Districts.)

Chapter 9: ENVIRONMENTAL AWARENESS THROUGH THE STUDY OF EARTH SCIENCE

By

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Pamilico County, a very small county of 10,000 in Eastern North Carolina, has no cities. The county has a large minority population and the income level of most families is very low. Much of their income derives from commercial fishing and farming and the average educational level of the people is below the 12th grade. There are four schools in the county; 2 elementary schools, one junior high school and one senior high school. We have no military bases and no industry except for a small garment factory. There is some tourist trade since the area has abundant water recreation facilities.

Although the students came from a coastal area they seemed completely unaware of their environment. They did not understand the balance of nature, the intricate food chain, the erosion of the coast, the dangers of pollution, or the economic implications of any of these. Their parents' incomes depended almost wholly on natural resources but they also existed without a critical awareness of their environment.

My frustration over the students' complete lack of awareness of their environment caused me to begin attending workshops and seek out resource persons with materials and information suitable for 8th grade students. I went to three outstanding workshops; Summer Seashop on the Bogue Banks through Sea Grant, a workshop at North Carolina State University's Science Education Department, and an Island Ecology workshop on Andros Island in the Bahamas with a Grant from the National Science Foundation. The island Ecology Workshop at Andros Island was the precipitating event which made my ideas of a new science program progress from a latent to a more concrete stage.

The first year I taught at Pamilico Junio High I remained wih the regular Earth Science curriculum as outlined in the textbook. The second year I took more liberties and, in the third year, the prinicpal and the supervisor trusted my competance and gave me complete freedom to implement a new program. This freedom allowed the change to come on gradually to meet a need. The second year of teaching gave me a beginning and the third year of teaching gave me the freedom and competence to expand and innaugerate the program in the community.

After my second year of teaching at Pamilico I attended the Island Workshop at Andros. For the balance of the summer, I outlined a tentative program for all the 160 Earth Science students and some 7th grade students who were in the Science club. During the teacher work days at the beginning of the third year, I contacted key personnel within the school system to plan for specific field trips and to obtain funds and support for the program. With their support the program began to evolve as a reality.

Throughout the entire school year I made trips to see resource persons, made numerous phone calls, and spent many week-ends planning the program in detail. Parents became involved and particpated in field trips, generating interest within the community. Local newspapers printed several articles on the field trips and the program in general. Since some 7th grade students were included in the third year of the program, as 8th grade students in this 4th year they now are able to understand the objectives of the program and conduct field activities without additional instruction. So, we now have a core group around which to build the program.

Our school and district administration has provided considerable support. They have arranged for school buses for some of the field trips, provided funds enabling me to attend workshops, hired substitutes when a field trip was scheduled which did not include all of the students, and given me personal support and encouragement. Additional and necessary support has come from the Soil Conservation Service, the County Planner, The Agricultural Extension Service, the High School Vocational Department, the local newspaper, and interested parents and community members. The teachers in our school cooperate by allowing students to miss their classes without penalty. Language Arts teachers also use the field trip experiences as a basis for creative writing and the seventh grade Life Science teacher has adapted parts of the program for her curriculum.

There was, however, a certain amount of envy among the other teachers because the Earth Science teacher was able to go on field trips and attend workshops. This envy became productive when a number of teachers began to schedule field trips so their own students would have learning experiences within their specific field. Then, the 7th grade science teacher joined with me on the Science Club activities to make the environmental program encompass Life Science as well as Earth Science.

Since I teach the entire 8th grade, I have students of all ability levels except those mentally handicapped students requiring a special Science program. There are 160 students in my six daily classes which range in size from 13 to 35. I also have from 1 to 3 study hall students in each classroom each period. The attitudes of students are as varied as their ability levels and it would be impossible to categorize any specific attitude as prevalent.

About 13 of my 160 students last year were above average and might be categorized as gifted and talented. However, very few of these 13 students are being encouraged by their parents to obtain a college education. In general, our students are probably average in their standard scores although last year their performances on standardized tests proved to be above expectations.

The Junior High School has 700 students and 35 teachers in grades 5 through 8. The building was once a segregated black school but, with integration in the early 1970's, it was made into a Junior High for all the county and some new rooms were added. There is a greenhouse, used by the vocational department, but no planetarium or environmental study area. There is nothing unique about our classroom. It looks exactly like any typical classroom in a Junior High School. My own is about 8 meters by 8 meters with 35 desks and one teacher's desk. I have the usual large blackboard and bulletin board. The walls are concrete, the floor is carpeted and the windows are all on one side. These windows, with venetian blinds, look out upon a small grassy area. A storage cabinet, two small sets of book shelves, and a table share space with an old bath tub which can be filled with water or sand.

While our architecture is nothing to brag about, we do have a good selection of equipment and supplies for studying the environment. Students use weather instruments, soil samples of Pamlico County, water testing kits, a small oceanography kit, coastal charts, aerial photos of Pamlico County and topographical maps showing flood prone areas of the County. We also have access to the vocational materials at the High School. All our materials and equipment are stored in suitcases in a lab upstairs in the same building as the classroom. As a result, students only have access to their materials when the teacher is present. When we schedule field trips the suitcases do make it more convenient to take proper equipment and carry it easily. This lab room is also rather ordinary with just six lab tables. I usually arrange for each table of six students to have a specific task to perform. When the lab is used, it is cleaned up by students at the end of the period, not by me.

It would be nice to have fewer students; 160 students plus a homeroom is just about all I can handle. The classroom would be fine if it were not crowded with 35 students and 1 to 3 study hall students. It is really difficult to individualize with 38 in our small room.

When I take students up to the lab and then down again at the end of the period. I often lose a few. Some duck into the bathrooms to smoke and some knock on teachers' doors as they go by. If the lab were next to my room it would be easier.

OUR PROGRAM

Our prime objective is to increase the students' awareness of the fragile environmental balance in Coastal North Carolina through individual learning experiences within the 8th grade Science curriculum. In becoming ready for this awareness, students collect and analyze weather data using appropriate weather instruments and systematic observation and recording. They read and interpret maps, charts, and diagrams relating to coastal North Carolina. These weather and climate studies are linked to the soil and organisms through water and soil analyzes and data they collect on organisms living in this area.

Students participate in many field trips to gather specific data on the area, visit resource sites, and meet people knowledgeable about our region: they also participate in seminars dealing with problems of the local environment. These seminars are usually led by specialists in the area of concern.

Every resource person emphasizes career possibilities for the students. Many of the students were limited to a very small area in terms of future careers before they received this information. Science students also develop individual research studies and projects for entry in local science fairs. Many students compete in regional science fairs as well.

On field trips, students are physically and mentally involved in the collection of data. Slide presentations and lectures are presented in the evenings when field trips are for a full week-end. Discussion groups and individual research are used in instruction during regular, in-school

classes. Science projects are deve
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Students show improved partici
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PROGR

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other students about surviving hurricanes and became the first Junior Hurricane Preparedness specialists in our area. Students look ahead to the future in order to become a socially responsible person in making decisions determing the future of Coastal North Carolina.

While Individualized instruction is difficult in large classes, students with the ability to do independent work are encouraged to seek additional information and ideas. The teacher plays a large role in guiding these students to materials and resources. Other students do individual projects and research reports as well with much of the program being taught on different levels to different students at different ability levels. These ability levels are reflected in all lab work, field trips, and field work where students in teams pool their information, come to conclusions, and make joint decisions relating their findings to their problems.

All cognitive material is taught at different levels to be within the grasp of each student and the affective curriculum is considered extremely important as well. Students on field trips develop patience with each other (and with weather and field conditions) and learn to respect and appreciate each other and the environment. Students usually have limited experience in this area and the field trips open up new horizons for them.

I try to make content totally concrete and practical with as little abstraction as possible. I emphasize content which is highly pertinent to the lives of students and the future of their community.

The program requires that the teacher look ahead at the possible future environmental problems of Coastal North Carolina. Teachers must be genuinely interested and see beyond present economic rewards and identify future ramifications of the very elements which are financially lucretive in our area now. If the teacher were more interested in the financial benefits of coastal real estate development, it would be very difficult for her to sincerely advocate this program.

I feel that the teacher, inquiry classroom and curriculum are so necessary, interwoven and interdependent that it would be impossible to eliminate one and still have excellence in the Environmental Awareness Program. The teacher must be creative, enthusiastic, well-educated and willing to give many extra hours of research and planning to initiate and maintain the program. She must be able to supervise student activities and encourage individual research and student participation.

Teachers must be flexible and creative; I cannot become enamored of my own lesson plan and force it on the students. A student's mood and attitude on a specific day may require an entirely different approach from the one I have planned. Field trips and resource persons may require rapid changes in plans. An inflexible teacher rapidly would become very frustrated.

I find that I need a solid background in science, a sincere desire to understand Junior High Students, a willingness to learn, the ability to be flexible and creative, and a high degree of energy and enthusiasm.

The inquiry classroom must never be static; it must have provocative bulletin boards, projects, fossils, live marine life and numerous stimulating experiences. Class methods must incorporate discussions, inquiry, slide presentations, seminars, and outside speakers. The changing format keeps students and teachers involved and interested.

A new teacher entering our program must have a belief in the goals of the program and a good solid foundation in Science concepts. They should also be creative, honest in self-evaluation, and have a real understanding of the needs of students. Such a teacher will have the support of the local administration if she recognizes our needs as well as her own and does not make decisions independent of authority.

The curriculum must be well-planned and sequenced with extra-curricular activities. If a text is used it must be meaningfully coordinated with the program. All too often, programs seem coordinated with texts--the reverse of what should be true. The affective curriculum is also important, as students develop self-confidence and stronger self-images as a result of their personal experiences. Teacher, classroom, curriculum; the three are equally important. Together, they build a strong and successful Environmental Awareness Program.

On field trips certain students are responsible for specific instruments and tasks. In being responsible for care of the instrument, they record and report accurate data to the group. All class and lab activities are grouped with a group leader with leaders being rotated so each student has an opportunity for leadership experience and responsibility. There are informal evaluations and no students are permitted to ostracize or humiliate other students although these behaviors are common in other classes and outside of school.

Flexibility is truly a necessity. Some weeks students spend all their time on purely academic activities within the classroom. Some weeks may be spent preparing for and taking field trips. Other weeks may be spent in the lab and, when important audiovisual materials come in, they must be seen within a specific time period. Resource people can only come on specific dates and, when they are able to come, other activities are rescheduled. While I schedule carefully, I am equally careful to see that I control my schedule rather than the opposite.

We use a junior high earth science basic text as well as supplemntary textbooks magazines, newspapers, and numerous printed materials from resource persons. I gather material from all these sources and organize it into a specific unit or series of lessons. Then I teach this material while gearing my instruction to the various ability levels of the students in a specific class. All material is available to students as they need it.

Field trips also are part of the curriculum and must be scheduled with an eye on the weather and an understanding that certain seasons are better than others. For example, winter with its high winds and strong seas is a perfect time to visit Cape Hatteras during our unit on coastal erosion.

Both in class and on field trips students are given many thought questions where there is no right or wrong answer. I encourag them to express their own opinion and offer possible solutions. I try hard not to ask questions to which I already know the answers. I don't want students to play guessing games; I want them to use their own skills, knowledge, resources, and logic to make decisions and arrive at solutions based on their own assessment and evaluation.

At the same time, I use a great deal of self-evaluation to see if I am really teaching what I hope I am teaching. I reflect back on what I have done, thinking about what I will do, and gather pereptions from my students. I also evaluate with short tests to see how much the children really know and understand. I seek comments from parents and resource persons and school administrators and try to learn from their criticisms.

Our major expenses are for field trips where we have bus costs, teacher substitutes, food and motel costs. Parents help with costs and some money is available in special funds such as through the Science Club. I usually pay for long distance phone calls related to trips. Sometimes I have bought the gas on trips and have paid for my own substitute. Paying for student meals and transportation is not unusual for me either. We do charge a science fee of $3.00 per child to help pay for instructional materials.

As a result, I can use any money I get. I also need money for field trips for those children who cannot afford to go. Although I try to pay for them but my resources are very limited and I can't handle it all. And, I also need many special materials for the children require a broad range of written and manipulative materials.

Our principal has gone on field trips with us and is personally aware of every activity as he helps to fit them into the school calendar. The Secondary Supervisor comes to school regularly to keep informed of our plans and ativities as well. I always plan with the principal and the Supervisor as they really are cooperative and seem delighted that our students are getting so many opportunities for non-traditional learning. I also get parents involved in field trips and Science exhibits. They actually help with experiments and help to supervise groups.

Between all the paper work and what it requires to teach 160 students each day, I will probably not be able to take as many field trips in the future. Also, I used a considerable amount of my own salary for expenses and I cannot do that indefinitely. The time spent in organizing and undertaking field trips has been hard on my family also. I take my two children along, if possible, but all these personal sacrifies are hard. I often wonder how long a teaher can maintain the energy to be really creative and still teach school.

MY DREAM

I would like this program to begin in the elementary school. Then, I would be able to teach the children in the lower grades so that they would have a better background and understanding before they get to the 8th grade. This might help make Science more important in the elementary grades and would enlarge on what I can now do. At present, science in the elementary school alternates with social studies and often must be short-changed to allow time for music and art. Math and language arts times are rigid and never changed. Even capable teachers in the elementary school simply do not have enough time or flexibility to do a good job with Science. I know I need time to plan as better planning enables me to individualize to a greater extent. As I see it, elementary teachers have little time to plan for science.

I also need less paper work. Now, every free moment has to be used filling out forms, doing folders, and filling out more forms. Every discipline problem requires a special form (and sometimes several) and instructional materials require requisitions. There are numerous questionnaires to be handed out and collected in homeroom and there are parent permission slips for everything.

My dream also includes more funds, free time during the school day for conferences with resource persons, and an aide to handle some arrangements for field trips. I would like to buy more periodicals for our resource collection and updated material in all areas of science.

As powerful and vivid as my dream is now, if my schedule remains as strenuous as it is now, I think I will just get tired. I'll either have to leave teaching or else stop being creative in order to survive. I hate to think of leaving out the creativity for, if I wanted the program to fail, I would stop caring about the children and quit dreaming up new activities. I would just give them written exercises out of the book and try keeping them quiet.

Now, I keep going because I love the job and find means of reward even though most of the rewards for teaching are personal. I can see the children learning to love science and not hating it as a subject. I can see that they are becoming motivated to learn and I see their attitudes changing. Discipline problems seem to disappear as the students get interested. These are rewards which are truly meaningful.

Those rewards are somewhat intangible. The only tangible rewards have been a plaque from the soil conservation service in Bayboro, N.C., an invitation to speak at the North Carolina Science Teachers Association, and recognition as a National Exemplar from the National Science Teachers Association Search for Excellence in Science Education.

The workshops where I learned specific Science skills were great and personally rewarding as well. I have found workshops inspiring and a means of introducing me to new skills, ideas, knowledge, and people. Teachers need to get out of our classrooms more often and into good workshops where the emphasis is on broadening horizons through learning new ideas and sharing with other adults. In the future I hope workshops will continue to provide one way of keeping me updated and providing fresh enthusiasm for teaching and this program. At these workshops, as I meet resource persons, and learn new skills helpful in enriching the students I become inspired once more. Workshops are a great help and motivation to me. If I can keep finding more rewards like those I have received, I will have the inspiration and energy to continue what I view as a most important program for our students and our environment.

The help and inspiration I have received has been rewarding as well. The following individuals provided materials, came in as resource persons, helped arrange field trips, and gave support and encouragement throughout the program! John Sanders, Coastal Weather Specialist, North Carolina Sea Grant College Program; Ray E. Ashton, Director of Education, North Carolina Museum of Natural History; Lundie Mauldin, Marine Education Specialist, University North Carolina Sea Grant College Program; Jo Ann Powell, Education Director, Hampton Mariners Museum, Beaufort, North Carolina; Dr. Ned Smith, Sally Nunally, Hilda Livingston, North Carolina Marine Resources Centers.

Chapter 10: Audio-tutorial ISCS

By

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Sioux Falls, the largest city in South Dakota with 81,000 people, has four junior high schools. It is located on the eastern edge of the state near the Iowa and Minnesota border. The city contains several light industries, the largest being John Morrell meat packing. Other large employers are Litton's Microwave plant, Citibank's credit card division and three hospitals. Sioux Falls is the location of the EROS Data Center, the University of South Dakota Medical School, and Augustana and Sioux Falls Colleges. Parents of students at Patrick Henry are largely middle class to upper middle class. There are fewer than 3% minority students and our philosophy is one of a basic mid-western conservative, family oriented population.

Patrick Henry Junior High with 1065 students in grades 7, 8, and 9, has a professional staff of 2 principals, 2.5 counselors, 65 teachers, and 5 certified aids. The main building was constructed in 1958 and a science wing was added in 1970. The three double classrooms and a storage area are equipped with perimeter lab activity counters and islands with water, gas, and sinks. Each double room accomodates 60 students with audiotutorial carrels present in each classroom. Each of the four junior highs has had a 6 room science addition built in the last 12 years.

The 7th and 8th grade room is 35 by 70 feet with a folding door down the center that is partly closed. Each end of the room has an equipment cart accessible to students. Counters and islands with water, gas, and sinks form the perimeter on two sides of one of the double rooms while carrels form a third side and the folding door the fourth. The 7th grade end has a plant mobile for use in a plant unit and the students work at two-student tables in the center and at the perimeter islands.

In the 8th grade end one corner of the counter is used for the chemical dispensing area, dry powders on one wall and liquids on the other. Each room has a fume hood with an exhaust fan for use with nitric acid and iodine tests. The room has a fire extinguisher, a fire blanket, and an eye wash station. The center of the double room has equipment for the storage of glassware and other equipment that is unique to the course. The perimeter counter has test tube drying racks.

The 9th grade room is carpeted with carrels on two walls. The students sit at two-student lab tables that are positioned in rows in the center of the classrooms. Equipment is available on shelves along one wall and on a wall hung pegboard rack. There are two island counters with water, gas and sinks.

The walls in all rooms are used to display teacher prepared and commercial posters. Each room has a "flow chart" to help the student determine the unit progression and the required and extra credit units. The A-T carrels, cassette tape players, cassette tapes, behavioral objectives, and small group testing areas make the physical facility somewhat unique.

While the new science addition was in the planning stage science department meetings were held to deal with program needs. The need for a new program became apparent from a multitude of indicators. Most evident was student disinterest in the subject matter offered. Teachers were constantly revising laboratory exercises and lesson approaches trying to motivate students. Too few students elected to take 9th grade science and those who did were boys. From these meetings a new program was devised.

Articles about audiotutorial methods were read and discussed and onsite visitations were made to Indiana and Minnesota to view A-T installations. Attendance at ISCS workshops by the entire science staff led to many ideas and discussions. Finally a proposal incorporating ideas from the staff and others was submitted to the Board of Education and approved. Considerable inspiration came from Postlethwait's Audiotutorial Manual published by Burgess and an ISCS Workshop conducted by Jan Holman, Silver Burdett; Richard Wik, Burgess Publishing Co; Joel Padmore, University of South Dakota and Marvin Selnes, Patrick Henry Science Chairman. We also got encouragement and assistance from: Lee Conelly, AV Diretor, Sioux Falls Public Schools, T.C . Tollefson, Assistant Superintendent/Curriculum; and Dr. John Harris, our Superintendent of Schools

While we all were involved, Marvin Selnes provided the project idea and leadership at all grade levels as well as objectives and tests. Robert Simonson, T.R. Maursetter, and David Elliott developed objectives, tapes, and tests for Level I and II. Victor Rames wrote objectives, tests, and tapes for Levels II and III while Arlyn Thomas provided tapes and, along with LaVonne Zeeb, developed revisions for Level I. Robert Simonson also developed Basic science activities for grades 7, 8, and 9.

Most of 7th and 8th grade is physical science while 9th grade centers on earth, environmental, space and biological science. Most of our students take 10th grade biology as their required science course. In beginning this course, we developed a proposal and submitted it to the superintendent of Schools and the Board of Education. After it was approved, specifications were written for the needed A-T equipment. As a group we ordered text materials and supplies and worked through text activities that summer. The whole science staff was involved. Behavioral objectives, tapes, tests, worksheets, and supplementary materials were prepared and storage equipment was constructed. Then, we hired an aide and instruction began. Since the start of the program, tests, tapes and objectives have been revised several times. The recommendation of the Superintendent, the Board's funding, and the enthusiastic support of the entire science staff led to smooth implementation of the program.

We also made it easier by preparing ourselves for this new Audio-tutorial ISCS program. We read the ISCS professional modules and had three summer sessions to work through the text material, preparing the student instructional tapes, tests, objectives, visuals and storage materials. Some of us attended NSF ISCS Summer workshops sponsored by the University of South Dakota in Sioux Falls and Vermillion. Others visited schools using ISCS in Mitchell, SD and Hawarden, Iowa. Equally important was a visit to Patrick Henry by Charles Richardson, an experienced ISCS Teacher and Science Supervisor and now a Silver Burdett consultant.

The teachers have gained a greater awareness of individual student differenes. and how to take the opportunity to work with small groups of students as well as individuals. Most of our teachers now place more emphasis on behavioral objectives that stress action verbs such as observing, classifying, measuring, predicting, and testing.

Equipment used for experiments is stored on carts that are specially designed for most of the special equipment. Objectives are kept on racks of file-cabinets while pre-tapes and summary tapes are kept in a cassette storage cabinet accesible to students. Each student's notebook and other stored materials are in trays and shelves in the classroom or science storage area according to class period. They are made available to the classes as needed. Books are not checked out to the student, but are stored around the perimeter of the room on book shelves. They are accessible to students during the clas period and may be checked out over night if needed. Four minutes of time are allowed at the close of the class period for student clean-up, return of equipment and room inventory.

Patrick Henry students are of all ability levels. Seventh and eighth grade classes are 60 to 62 students with two teachers and one certified aide. Ninth grade classes average 30-32 with one teacher. A majority of the students are of the middle to upper class with others ranging down to the poverty level. One-half of the students are the children of busines and professional parents.

PROGRAM GOALS

Our General goals are for students to:

1. develop self-reliance
2. grow in social responsibility
3. develop scientific literacy
4. develop an interest in science

We provide a variety of activities, both ISCS and supplementary which lead to these goals. The 7th and 8th grade classes include units on alternative energy soures and conservation of present energy sources. Ninth grade units; **ISCS Environmental Science, Well-Being,** and **Investigating Variation,** include examples of human adaptation and references to alternative futures. Ninth grade uses a supplementary energy unit and **The Search For Solutions** film series as well. Inquiry processes are an integral part ofthe methodology of the **ISCS** curriculum. **The Search for Solutions** film series presents interesting uses of inquiry also.

Students in our program do pretty much what any ISCS students do. But, in addition they are listening to preview tapes, listening to summary tapes, and taking small group oral tests with the teacher.

At all levels students meet success in the science classroom, thus maintaining a positive attitude toward science and science classes. The teacher has an opportunity to discuss science related occupations with the class as a group as well as with the individual students. **The Search For Solutions** films as well as other films used throughout the year also provide information concerning career opportunities.

Our program is self-paced and uses an audio-tutorial format to assist the student. Each student is in class one class period per day for 47 minutes per period or 235 minutes for the week.

Students work in pairs during the lab activities and select the work pace that is most comfortable for themselves and one that will yield the desired unit grade. The program is activity oriented and students have freedom in the selection of some of the text excursions while others are required for remediation.

Problem breaks in the text and small group questions use personal knowledge to study social applications of science. Students play a key role by making choices on which excursions to take and which problem break or project to do. The student is the c· ›n core of experience. Small group evaluations are based upon behaviora objectives. The tests include graphic interpretation and problem solving situations.

Our teachers have participated in a study of Piaget's work in developmental cognitive psychology. We test all students to determine the level of formal and concrete thinking and consider aspects of this psychology as we develop activities and as we teach. Some of our study and activity development was funded through Title IV-C grants.

Teachers are very committed to the students' welfare, as demonstrated by self-pacing by the student rather than group pacing. Teachers work with individuals to arrive at a pace that allows for the greatest amount of learning by each individual. As a result, each student meets success and the teacher is free to work with remedial activities. All activities involve hands-on experiences where we think of the teacher as more of a facilitator of learning than a disseminator of information.

Students are capable of success and will strive for successful experiences. When we let students plan instructional work periods the teacher becomes less threatening and is looked at as a helper.

Students self evaluate when they are prepared to do so. Generally, before a self-evaluation, they listen to preview and summary tapes, study the chapter objectives, and review their notes on activities. In addition to self evaluations one of our program goals is teaching social responsibility. We provide systematic opportunities for this by giving students responsibility for much of their learning as well as responsibility for inventory and clean-up at the close of each class period. We find students becoming more responsible and becoming more self-reliant.

Teachers prepare laboratory materials and monitor student progress as well as developing, testing, and revising all objectives, tests and tapes. Teachers also prepare slide sets to illustrate equipment procedures. In addition to all the ordinary tasks which teachers do our teachers are involved in activities unique to this exemplary program.

Teachers are working with students individually or in small groups on laboratory activities, preparing materials and reagents, or giving small group evaluations. They may be correcting tests and notebooks, meeting with other science teachers to plan activities or reading science professional literature to improve their own knowledge and develop curriculum. Teachers actively assist students with science research projects, and make-up work. We don't spend all our time using inquiry techniques and skills; we also repair equipment. But, even then, we try to avoid giving students too many answers.

Our focus on Inquiry includes an alertness to wait time, use of proper questioning techniques to get something other than memorized answers, and appropriate classroom organization.

Aides assist in the classroom and correct a majority of the notebooks. If they are not available it increases the teacher work load considerably and reduces the amount of quality time which teachers have for working directly with students.

We use THE SEARCH FOR SOLUTIONS film series, filmstrips to accompany the NATURAL WORLD, ENERGY CHALLENGE videotapes plus other films from the South Dakota Office of Energy Policy and other sources. These materials are used during special emphasis units providing students with current information on energy alternatives and conservation, present reserves, and current issues.

Student interest is shown by above average enrollment in elective courses. Students have a positive attitude toward the class and are willing to work before and after school on a voluntary basis. They talk to their parents also. When the program was threatened with cancellation during a K-12 study and all of the junior highs were scheduled to offer the same curriculum, parents were willing to testify about the positive aspects of the program. Students compete with 9-12 grade students and win more than their share of the competition. Teachers are enthused about teaching and express pride in the work being done.

While parent involvement is not an integral part of instruction, parents do provide students support and help with homework. We inform parents of their student's progress and a list of work that can be done outside of the classroom is provided to each parent.

Our administration has supported us completely. Their support initially enabled the program to be started. Then, their support allowed us to write proposals to fund a variety of implementation activities and development of computer programs. They also have provided funds to travel to conventions and conferences and to support our budget. They are very flexible about granting permission for students to attend and participate in contests.

The principal provides an atmosphere of acceptance and concern as well as approval of the program. The administration, however, plays no direct instructional role. They approve all proposals and requisitions, schedule science classes in consultation with the department representative, and provide evaluation of the professional staff. But, they are not involved in curriculum or instruction.

We have a curriculum study committee which, with the advice of teachers, recommends material purchases to the Board of Education through the Superintendent. A Staff Development Committee for the District and a building In-Service Committee recommend staff training opportunities and formats. Some of our inservice was provided by outside funding. We are considering proposals for the district staff development program.

We feel the best interests of the students must be first. Any program changes must improve the efficiency or quality of learning. Our strategies for learning must be based upon the student's developmental level or we know they will not lead to true understanding.

Professional organizations, especially the **NSTA** Conventions have served as a tremendous source of inspiration, information, and ideas. Their continual emphasis on excellence and work toward that end have been valuable and allowed us to realize that we are not alone in our quest. Our teachers regularly read **The Science Teacher, Science and Children, The Physics Teacher, The American Biology Teacher, Science Education, Journal of Geological Education, School Science and Mathematics, South Dakota**

Science Teacher, Environment, Science 83, Astronomy, Science News Letter, Smithsonian, Natural History, National Wildlife, Phi Delta Kappan, and several computer publications. We read a lot of journals, we get a lot of ideas and keep current and professional.

We don't expect much change in our goals. We do, though expect to change curriculum as needed to maintain relevancy and meet new needs. The energy units have been added in the last two years and possibly more ISIS units will be added to keep the program consistent with the new curriculum to be adopted in 1983. Our other three junior highs in the system have not adopted the ISCS, but use a text-entered, group-paced program. Patrick Henry has requested an exception to the adoption and is receiving support while writing it. We would like to add more Earth and Life Science units to be consistent with the new curriculum as well. Our plan also includes more use of microcomputers, especially at grade nine.

Exams, worksheets and tapes are continually assessed and revised as needed. All ninth grade tests were changed in 1981-82 and parts of the 7th and 8th exams were changed in the last two years. Tapes are changed as well. These changes are made to facilitate student learning and reduce problems noted in previous activities. This is one very obvious benefit of developing our own curriculum: we can revise as we need.

We could be even better if all teachers on a grade level had the same planning period. Now, our student number make it necessary to have classes during all periods so teachers can never really get together easily. This would improve communications and provide a common time to work on revisions, new activities, and think of the future.

We would like to continue the Piaget In-Service program and spend time studying ISIS and other inquiry texts and articles. It would help if more of us could attend conferences and conventions. We also would like to study questioning techniques and develop questioning strategies and skills which would increase our power in the classroom.

We feel that teachers who read professionally, revise materials, propose innovations, and are dynamic would fit in well with our staff and program. These are the kind of teachers who listen to parents, students, and others. These teachers are concerned with communicating.

We have conducted interviews with selected students and parents and found them useful in developing revisions. Surveys of past graduate, including present 10-12 graders, would be useful as well. More and better revisions would make us more consistent with Piaget levels of students and would provide additional activities and reading to meet student's needs. We also need to include more material stressing science and society issues. These would enhance our relevancy at the same time. These changes should lead to improved learning and greater student interest.

Our program would fail if we lost our current good teachers by transfer or resignation and replaced them with teachers who do not accept self-pacing and inquiry teaching. Or, if the administration denies our request for curriculum adoption exceptions, our program will instantly disappear.

Our program has been very successful in encouraging students to enter science competitions. We also have won more than our share. We have had two Space Shuttle Regional Winners, and two International Science and Engineering Fair participants. Two of our students entered the South Dakota High School Physics Contest and took third place. We were the highest ranking South Dakota School in the National Science Olympiad Test and we won two of five South Dakota Research Grants for students. At the South

Dakota Junior Academy of Science, 11 of 43 papers presented in 1980 were Patrick Henry students and 17 of 49 presented in 1981 were our students (The Sioux Falls Board of Education has only allowed junior high students to participate the last two years.) We have State winners in the National Energy Education Day each year.

If we wanted to implement our program in another school, we would suggest that teachers read alot and spend time with us visiting and teaching in the Patrick Henry science classroom. Once you have an innovative program you must write about and defend your material as meeting the needs of students before you have to defend the program itself.

Preservice teachers should study the psychology of learning and develop an awareness of professional growth. Preservice students should be encouraged to read professional journals and show commitment to education as a profession. Examples of and development of inquiry activities.

We expect new teachers to approach the program with an open mind, be commited to reading professional journals; and have a broad background in all sciences. These teachers need a belief in success and pride in a job done well. If they do, they will be working in a program that students and parents enjoy, appreciate, and acknowledge as successful.

Chapter 11: Introduction to Scientific Research:

A Summer Science Research Program

By

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Spartanburg, a city of 44,000 located in the Piedmont area of South Carolina, is 42% minority. This textile community supports a large variety of socioeconomic levels and cultures. In addition to textile plants, several metal working and machinery factories, food product industries and ceramics plants are found in the community. Sixty-six firms representing ten nations are located in Spartanburg county, one reason Spartanburg is still a growing, prosperous area.

Spartanburg's District 7 senior high school, with approximately 2,300 students in grades 10-12, has 140 staff members including teachers and administrators. The initial structure was built in the late 1950's with more recent additions and renovations completed in 1974. The mood and atmosphere of the high school are those associated with a tradition of excellence. This tradition is being maintained by an enthusiastic and dedicated faculty and staff. In addition, the community expects quality instruction. Consequently, we have a setting condusive to learning in a controlled but relaxed atmosphere.

The science wing was completely renovated in 1974 with science teachers doing much of the design work. Now, there are separate laboratories for the advanced placement chemistry and physics students, a radiation lab for carrying out experiments with low level radioactive isotopes, and a balance room with a special isolated table. A shop with extensive power woodworking, metal working, and welding equipment supports the fabrication of new devices while a glass blowing bench, compressed air to the advanced placement chemistry lab and demonstration desks, and a steam pipe to the AP chemistry labs enhance the range of activities available to our students. The science area also contains darkrooms, a chemical preparation room, a chemical storage room with special collapsing wall in the event of explosion, and a greenhouse with climate controls.

The biology area has an animal preparation room, an animal room for housing and growing animals, and six new biology labs with five offices. Each biology lab contains a preparation and research lab as well. Every laboratory is equipped with an environmental center while the AP biology laboratory has an herbarium and its own darkroom. The science wing also houses a computer center. Outside, we have a nature path for year-round student field study.

Our summer science research program was initiated in 1963 by a chemistry teacher, Mr. Robert Gettys, who is now an assistant principal. The program developed from the atmosphere created by the 1960 space age excitement and his desire to provide far more science achievement at Spartanburg High. We had a great need to upgrade our science teaching staff and help keep them abreast of scientific research and, at the same time, a need for a more open-ended science experience for high ability students. We wanted to compete more successfully with students from the other districts and counties in the local and regional science fairs as well.

Our students are generally above average in ability and have a strong interest in the sciences. Many are looking in the direction of science or engineering as a career. Each summer we have from twelve to twenty-four students in a course designed for students who are self-directed to a large extent. The course is not designed to deal with specific handicapps or problems that students may have but students with varying emotional and learning disability problems have been successful. The students are mainly from low to upper middle socioeconomic status families with a positive attitude and a desire to work diligently toward a solution to the problem under study.

OUR PROGRAM

Basically the program emphasises the scientific method of problem solving while introducing the student to the elements of research. We also visit research facilities where research scientists explain and show students evidence of applied research while discussing the differences between basic and applied research.

First, we want to introduce students to the fundamentals of science through research by giving them an opportunity to identify and state a problem for study. We give students experience in personally formulating and devising experiments to test their hypotheses. Collecting and analyzing data and presenting it as a written paper and an oral report to his classmates and faculty is a final experience for our students. In the process, students become familiar with the rudiments of literature research and the use of abstracts, readers guides, journals and other reference materials. We introduce students to research facilities as well as men and women who are actively involved in research. We feel strongly that an opportunity to interact with scientists and other students in a relaxed atmosphere leads to pooling experiences and gaining knowledge which can provide solutions to problems. In observing students over the years I have noted that many increase their SAT scores to a large extent through the experiences in this summer program. The needs of the students are uppermost in the minds of the faculty and we want to provide an opportunity for developing emotionally as well as intellectually through an experience that leads to success.

We encourage students to use problems in the area of their greatest interest. Many times their choices relate to social problems such as alcoholism, diabetes, or possibly the energy crisis. We have been pleased with the success of our students over the years. For example, one student became interested in alcoholism and devised a means of inducing alcoholism in rats so he could study the removal of the pineal gland as a cure for alcoholism. He was able to remove the gland successfully in a number of rats. By discussing student projects in the area of environmental problems we try to make students aware of the scientists and others have on their enviro how these decisions relate to their own wo

The problems that the students choose chemistry or physics or biology or astron place them in the particular laboratory si major part of their work will be done. Fo working with chemical solutions or making chemistry lab under the direction of the able in the area of chemistry. Students w nutrition studies or with animals would b is true with students working with plants thing in astronomy would be in the physic photography or holography would be locate the students are not singled out as bei because they are in science and can learn as each other.

The problem solving techniques lear alone but are useful in any area of life. we deal with the students in groups or ind lem solving is not simply something that t science classroom but something they take is part of their thinking process and impo which they happen to find themselves. The most students choose problems that they ca

By introducing students to profession scientific work fields, we give them ca understanding of the nature of science, careers. Many times we find students w related to the problem area dealt with in

Students become aware of industrial research facilities that are in the comm the market place.

During our group sessions we emphasiz sibilities students have toward themselves Many interesting topics last summer were i and the changes, problems, and responsibil

One student dealt with the effect of tles, another student studied the medical ermining certain aspects of juvenile diabe interested in the nutrient value of cert Still another student investigated the different types of music such as classical

The course has no specific content cu the student's choice of problem dictate study. The flexibility of the program is chooses his own area of study and, to a l the solution of his problem. The emphasi method and procedures used in the method it for its value in seeking solutions to p

Students have assigned work areas an who is having difficulty and discusses wit

Periodically group discussion periods are held where students relate the progress they have made and the difficulties they have encountered. This provides opportunities for other students to offer suggestions and advice and provides an exchange of ideas and scientific knowledge while creating enthusiasm and interest on the part of students and teachers.

EACH DAY

In this summer programs students play a vital role in the scheduling of work time. After a brief daily meeting which may last from ten minutes to more than an hour the student is then involved in his workstudy time. Students plan a daily schedule and are responsible for fulfilling their daily, personal goals. Students have been given roles of leadership in personal management, planning, and decision making. We make certain that each student takes an active role by placing each on a summer science committee. There is a book committee responsible for making sure that books are returned to the libraries on time; a shop committee responsible for tools and their care; a social and recreational committee responsible for developing esprit d'corps among the students and planning social and recreational activities including swimming parties, rafting down nearby rivers, tennis tournaments and weiner roasts.

We encourage students to come in each morning with a goal already set for the day, a plan, and then to finalize their work. Students log into the program in a central book each day and then log out. They are responsible for doing their own research papers and other things that are involved in personal evaluation.

Students meet in a central classroom at 8:30 every morning for an initial information and exchange period. This period may be from 15 to 90 minutes long depending upon the circumstances. Planning for a trip or checking on the return of books to libraries, instructing students in the use of abstracts or in procedures for writing their paper may be covered at this time. This is generally the time films are shown as well.

We show the film series "Search for Solutions" since we have found it helpful in developing an appropriate attitude toward research. The remaining part of the day teachers are working with individual small groups on different aspects of their projects. Students spend several days in local college libraries using abstracts. Then, they go to Clemson University to use the more extensive library facilities. Students also visit local research facilities such as the Milliken Textile Research Center, the CRYOVAC Company which is a division of W.R. Grace, the HOECHST Fibers, and the Savanna River Nuclear Plant. With a group of 24 students, each doing different studies, there are a seemingly unlimited number of things that have to be secured for the students.

Teachers avoid allowing the students to become dependent upon the teacher for answering questions or doing procedures that are clearly within the grasp of the student. Teachers have to recognize, however, that students have never encountered this kind of situation before and may be prone to becoming discouraged. Continual encouragement enables students to gain confidence in their own work. Students are given a notebook at the beginning of the summer program and they are asked to divide it into several sections. The first section is the daily log which they complete each day including a section for lecture notes and a section for unsolved problems. They list these problems as they go through the summer. They encounter these problems when someone talks about them or in their reading. They also have a section called "library notes" where they make a listing of abstract numbers and reference materials they may want to use later.

Students are encouraged to learn through reading, interacting with other students and teachers, and experimentation. Although an individualized approach to learning with open ended inquiry is emphasized, total class general sessions are called at least weekly giving students an opportunity to tell about their progress and raise questions about other student's work. During these sessions current news items related to disease or other social issues that have relevance are discussed as well.

When students have stated their problem and have an experiment plan approved, they make a list of chemicals and materials needed. These come from the stockroom or they may be ordered. Students go through science material catalogs and locate what is needed and within their budget. Students keep their chemicals and equipment at assigned work stations and are responsible for maintaining their own work space.

Key books that we have available are Wilson, **An Introduction to Scientific Research** and White, **Introduction to Research**. We use these as reference material without assigning students a book. They are not asked to read or report on the text material, only to understand and use it. Students also are given outlines of a format for written reports used by the South Carolina Junior Academy of Science, giving a consistent reporting instrument for research work.

On several days, outside speakers present their ideas, discuss the excitement of research, and instruct students on various types of research. During the final days of the program students present their project in an oral form while their presentation is video taped for later use and analysis.

The program is based on an 8 week period running concurrently with the regular summer school. These weeks are loosely divided into four areas of concentration; the choice and statement of the problem and searching the literature, design of experiments and assembly of apparatus, the execution of the experiments and collection of data, and evaluation and reporting of the student's work. Obviously this order can not be followed in all cases because of the individual nature of the program. It does however, outline the direction we expect the student to proceed in his research work. Students are free to choose any area of interest for their research and usually narrow this in an interview session with the teachers. This narrowing of focus is necessary because student time, equipment, chemicals, and program funds are limited. The only cost to students is the regular summer school tuition.

While students must spend a minimum of 120 hours during the eight weeks, an average of 15 hours per week, most students spend well over 200 hours at this investigation. Faculty members are present from 8:30 to 4:00 each day with the number of faculty members present depending on the number of students that will be working. Although this activity takes place during the summer, the flexibility of the program allows students to be with their parents and family during vacation.

The teacher in this program must perceive the student as the problem solver and not as a student who simply absorbs knowledge and regurgitates facts. Teachers must encourage students to experiment and try new things even though they feel that it is not going to work. Students should be encouraged to find what happens when certain things are carried out.

Teachers encourage a sense of curiousity and interest by presenting interesting demonstrations and posing questions. They involve students in arriving at solutions and raising questions which develop into significant studies. One of our students became interested in the blue bottle reaction presented at the beginning of the summer program and his studies began at that point. This sense of inquiry eventually led him to be recognized as a Westinghouse winner.

Teachers give instruction in techniques but use an open approach with students in the research activity. They pose questions for students to consider and allow student opportunities to experiment. Philosophically, teachers view themselves as catalysts.

Each teacher presents special topics of interest. For example, we may have a presentation on wave phenomena followed by presentations on light or laser, holography or chemistry demonstrations. Some spectacular reactions may include the blue bottle, dust explosion, thermite, and potassium permanganate and glycerine reaction.

Teachers must be careful to keep the program student-centered and assure that periodically news media report the work of the students and the awards and recognition they have received at the state and national level.

We would like to add more visits to laboratories and industries with additional visiting lecturers to enhance the depth and body of the program.

Teachers must employ the scientific method of problem solving. They must have experience in laboratory or industrial type experiments. The teacher is assuming the role of research director and provides a sounding board for novice researchers to draw on; a source of ideas and suggestions enabling him to overcome the hurdles he continually faces. The student, being the researcher, needs someone with a good background and experience who can help him in talking through problem solving situations but not necessarily giving him the answers to questions. The teacher's role is pointing him in the direction he needs to go to solve his problem.

The skills we would like a teacher to possess are laboratory techniques in the area of his field; a basic understanding of the elements of a controlled experiment; and the ability to use the reference materials in the library including the readers guide, the science and technology index, the abstracts and the chemistry, physics, and biology journals. Of course, knowledge of other reference materials that are available in the library would be useful. It is very useful, as well, for teachers to be adept in the use of hand tools for fabricating equipment. It is important that teachers be able to instruct students in these skills since they must be guided due to the potentially hazardous nature of the activity.

Our staff members hold membership in NSTA, NABT, and AAPT and read the journals regularly. These journals provide new demonstrations for teachers and are a source of project ideas for the student.

EVALUATION

The open-ended nature of the program does not lend itself to an objective evaluation system for we feel that tests would be a discouraging factor. We try to make this a learning experience that is as student-oriented as possible by providing an atmosphere where the students begin to appreciate and enjoy learning. If we were more traditional, including traditional exams, we would fail.

Four measuring criteria form the basis for evaluating students; 1) the daily log book, including daily activities, the literature search information, and problems, 2) a written paper following a suggested outline, 3) an oral presentation which is video taped, and 4) the student's scientific attitude including interest, ability to organize and carry through with work goals, creativity, curiosity and understanding, and applying scientific principles. We do not administer any tests of knowledge or laboratory skills. Our evaluation is based on the four criteria, scientific attitude, and the self direction of the student.

Weekly, the staff meets to discuss the progress being made by individual students and to assess the program. At the end of each summer session ideas are recorded that could lead to a smoother, more effective program for the next summer.

I think it is significant to note that this program has not been directed from the administrative level. The teachers on staff work closely with the administration, however, but no guidelines or number of students enrolled is set as a basis for the program. This is important in order that the staff knows they have summer employment. This past summer we increased the number on the staff from three to four due to the increased number of students participating.

Our program is successful as evidenced by the honors received by our students. For 1983 we have 16 students who are National Merit Scholarship semifinalists, more than any other public or private high school in the state. Over the years SHS has ranked among the schools having the highest number of National Merit semifinalists in the nation. Two students are finalists in the 1983 national achievement competition, nine students are commended by the National Merit corporation, and five students in the past three years were finalists in the Presidental Scholars competition. Students at SHS may prepare for advanced placement examinations in thirteen areas, more than any other high school in the state. We think the following comparisons are interesting: in 1969 there were 78 Advanced Placement examinations given in the school; thirty-one students scored three or above. In 1982 there were a total of 170 examinations with 127 three or above. Sixty-six scored 4 or 5, the highest possible scores.

Of the graduating class of 1982, 76% are attending 61 institutions in 15 states. Our '82 seniors in the class of 82 won scholarships worth $704,000 for four years. Not included in this figure is any need-based aid such as the South Carolina tuition grants or basic opportunity grants. Our 1982 seniors averaged 41 points higher on the SAT than the state average and 6 points higher than the southeastern average with sixty-seven percent of the 1982 seniors taking the SAT. Science Olympiades research projects and competitive testing produced more than our share of state and national winners. The State of West Virginia hosts two senior science students from each state for a three week science camp. Eleven students have been selected from Spartanburg High School since 1972.

The American Association for the Advancement of Science each year selects two outstanding research papers, inviting the authors to attend the national meeting. Since 1970 seventeen of the twenty-four state winners have been from Spartanburg High School. And, since 1972, three of our summer science students have been among the top forty Westinghouse winnners. The South Carolina Junior Academy of Science was founded at Spartanburg High School in 1969 and now has over 2000 members. Our summer science program, established in 1963, has had an enrollment of over 300 students and serves as a model for many South Carolina schools.

A survey of past graduates would be interesting and useful in validating the importance of the program especially as it aids in career choices of the participants.

The most significant expense is the salary of the faculty members, an amount that is variable based on experience. The amount that is directly involved in program expense is approximately $100 per pupil, including transportation and material costs. From the beginning the program has had the backing of the school board, local principal and the district superintendent along with the assistant superintendent of instruction.

The success of the project comes from this support of our school board and superintendent who continue to provide money and community promotions. The program also is blessed with staff members who are talented and devoted to the project and give much time and effort to see that it succeeds. It has been a cooperative sort of effort between community and administration and the teachers over the years with the community providing support in allowing students to visit research facilities and speakers for areas that we have requested. It will continue because we have young teachers on the faculty, two of whom are former students in the program and are now teaching chemistry and physics in the science department. We feel that these young people will be able to maintain the program on this high level or even higher than what it has been in the past.

Parents are involved initially as students are being recruited to the program. At this time parents are told about the program, the success it has enjoyed over the years, and, in addition, the parents and students are shown the facilities available for the students to use during the summer program.

The assistant principal of instruction sends letters to prospective students in the spring and he or the principal welcomes the students and parents to the introductory meeting.

The administration supports our problem by providing summer salaries for the faculty, leading to better staff maintanenance by placing teachers on 11 month employment and easing some financial restraints. In addition, the opportunity for teachers to keep abreast of what advances are being made in their respective areas is a positive influence. More importantly we see young people come alive to the potential they have to do something that could make a difference.

In general the role of the administrators is to provide support for excellent instruction by supporting the teaching staff and through discipline, building equipment maintanence and materials supply.

The principal is responsible for the number of staff members assigned to the program. His approval is sought for extended outings such as the Worlds Fair Trip or trip to the Fernbank Science Center in Atlanta. He is informed of tours and outings where school transportation is necessary.

Our teachers have been recognized for making this difference. Two of the four members of the summer science staff have received the South Carolina Outstanding Science Teacher Award and we have numerous certificate awards for student achievement in science from NSTA, Westinghouse, and other national organizations.

The flexibility of the program and the interest generated each year at the South Carolina Junior Academy of Science meeting also is one way we attract interest. The science teachers at the junior high schools are helpful in encouraging students to get involved as well. The most recent boost has been a meeting with prospective students and their parents in the spring in time to schedule the program into their summer activity.

The nature of the program is such that the commitment for support must come from the school board and administration. We feel that a dedicated teacher with a keen desire to work with young people can succeed. We feel the best results can be achieved with three or four teachers but certainly not less than two. The student teacher ratio should be one to five or seven.

I would like to acknowledge the assistance of Bob Ge[illegible]s, Assistant Principal; Joe Clarke, Assistant Principal of Instruc[illegible] and program staffers Seve Jeffords, Randy Mahaffey, and Major Rhodes [illegible] their contributions to the program and this description.

Chapter 12: Excellence in Teaching Science As Inquiry: Some Generalizations and Recommendations

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In chapter one we pointed out that if students are to use and truly understand the specific and general characteristics of scientific inquiry we need to provide more than mere dictionary definitions of inquiry. We need operational definitions and themes, with specific goals and examples. The synthesis Researchers, in analyzing and developing school issues related to teaching science as inquiry, developed three main themes Each theme is an important part of an operational definition of inquiry. These three themes; The Learning Context, The Transactions of Instruction, and The Outcomes of that instruction have been addressed by every teacher wishing to stimulate inquiry in science classrooms. The ten programs described in this monograph are no exception.

THE LEARNING CONTEXT

Developers of all ten of these exemplary programs have taken very seriously the contextual component, including curriculum materials, skilled teachers, science laboratories, and community involvement. While most existing school science programs may make this same claim, few are those who considered these elements ahead of more traditional notions of content, processes, and skills. Fewer still are these who designed their program with a full understanding of the role of context in the total inquiry program.

While most school science in the United States is textbook centered and classroom oriented, all ten of these exemplary programs use a personalized inquiry curriculum developed with their specific community, students, abilities, and needs in mind. As a result, these programs involve and respond to the community as well as the students. Shelley Partin's Pamlico County Junior High Environmental Awareness Program allows students to examine closely the fragile environmental balance of coastal North Carolina. In a relatively poor community where a majority of the population earn their living through farming or fishing you cannot provide a much more relevant curriculum. But, more than relevant, these students are learning what affects the environment, **their** environment, and are coming to realize that this is the forerunner of the environment they will inherit as adults. These students see Science as an important part of their lives, now, and a way of protecting their own future. These teachers have placed humankind in a central focus of study, much as in the Project Synthesis Desired State.

The community is the school yard for junior high students of Eva Kirkpatrick in Missouri, as well. These students took environmental inquiry several steps further than normal as they used legal processes and the courts to prevent a landfill operation in their community. Now, they are researching actively the Dioxan contamination of much of their community, including the stream running through the school grounds.

Some teachers, like Troy Bridges of Spartenburg (South Carolina) High School, have been able to plan and see built science laboratories and support facilities which rival those of many universities. Others, like Judy Holtz, a primary teacher in Broward County, Florida, have developed curricula which are unique but highly transportable.

All teachers in these ten programs are very committed to their programs and their students; sometimes to a most unusual degree. When we visited Merrit Island High School we learned that Patricia Denninghoff was in the school and available to students almost every evening, sometimes until early in the morning.

One of her students told us she was willing to stay all night if a student's project required it. We asked her student teacher, an eager young man who was obviously inspired by Ms. Denninghoff, what advice he would give a teacher wanting to set up a similar program in their own school. After a thoughtful few moments he replied, "Get an apartment over the school, remove the locks from the doors, run in extra phone lines, and don't expect many uninterrupted meals." Another person suggested she worked well with students because of her own nine children. But, a fellow teacher thought those same nine might be why she was at school so much!

We're not sure we have a common reason for involvement but all of the teachers in these ten programs work easily with students, parents, other teachers administrators, and community leaders. They all participate actively in professional organizations, read professional journals, and see themselves as learners. They do not see themselves as fountains of knowledge from which students must drink. These are teachers who value inquiry and an inquiry orientation in themselves and their students. In addition, they possess the skills and knowledge necessary to create an environment conducive to inquiry. One aspect of the creative, inquiry-oriented person which is most obvious in all of them is their extreme flexibility, including flexibility of time, schedule, curriculum, expectations, and themselves. In short, they all individualize instruction to some extent and some profess never to meet with more than a few students at a time.

Some teachers, like Marvin Selnes, Sioux Falls, South Dakota, have supplemented commercial curricula, like ISCS, and found ways to go beyond mere self-pacing. Others, like Patricia Denninghoff and Kenneth Marx of Merrit Island; Ann Justus, of Phoenix; Lois Durso, of Massachusetts; and Larry Fauque of Sunburst, Montana seem to create a different curriculum for each student. Actually, they let the students create much of their own curriculum; the teacher's role has become more that of a resource, an advisor, and, in some cases, a conscience for their students. Don Birdd at the Model Lab School in Richmond, Kentucky, emphasizes teaching "both sides of the brain" By these he means teaching more that the linear, rational thinking and learning usually associated with science instruction. He wants his students to expand their creativity in science, their concept of what science is, and their use of inquiry in classrooms.

Although many teachers in these ten exemplary problems seem to create what others might call an "unstructured" classroom environment, in reality they have very explicit goals for students and very concrete visions of their ideal classroom and the learning, values, and attitudes it will enhance. They maintain these visions in establishing a learning environment for their students.

TRANSACTIONS OF INSTRUCTION

Transactions, the second theme of the Project Synthesis Desired State, are the activities of students and teachers; the interactions of students, materials, teachers, others, and the outside world. While Context included some static elements like materials and laboratories, transactions are dynamic. Transactions are what students and teachers do while learning Science as Inquiry.

Inquiry classrooms must provide time not only for doing science but time for transactions involving reflecting, feeling, and assessing as well. The ten programs represented in this **Focus On Excellence** monograph do just that. Most science teachers provide reasonable laboratory time. But, while they do not prohibit feeling, reflecting, or assessing, teachers don't provide systematically for their occurence.

Many of the articles in this volumn mention the use of student self-evaluation forms, student attitude, and students creating their own plans for learning. Some programs provide daily and weekly self-assessment, others are less regular. Some use self-reporting forms or checklists, one uses videotape of student presentations, and others rely exclusively on regular student-teacher conferences. All, however, provide students with opportunities to look inward, to determine for themselves the value of their own endeavors. The programs do not view student evaluation as the exclusive domain of teachers. They recognize fully that true scientific inquiry includes self-assessment and evaluation as a precursor of continued progress and scientific inquiry. Students who cannot self-evaluate can inquire only to a limited extent. So, as in these ten examples, self-assessment and evaluation must become real goals of any serious program promoting the teaching and learning of science as inquiry.

Part of this self-assessment comes from student originated questions, part from teacher expectation and mandate. But, only the teacher can structure the classroom to eliminate that ever possible bain of student self-assessment; continual assessment and evaluation by the teacher. As one teacher pointed out, "If I want **them** to make the observations I must teach skills and create opportunities for observation; I must be cautious not to make the observations for them as that defeats the purpose and makes them dependent on me. If I want them to be competent self-evaluators, the same technique holds true."

Many of the goals of these ten programs are similar in that they require the student to **do** something both as a prerequisite and as an indication of learning. These teachers do not view mere knowing as very important; they want students to be able to apply and communicate their knowledge in identifying and solving problems or structuring additional knowledge. They want student knowledge to lead toward other goals such as interpretation of their environment or an enhanced science literacy. Through **doing** science teachers in these exemplary programs want students to come to understand the nature of science; its tentativeness and man-made nature. These teachers indicate that for students to be science literate they must know and know personally **how** science comes about; its limitations, beauty, and nature. Students who possess only knowledge of science without reflecting on and feeling the thrill of discovery, the agony of defeat and the struggle to know, are hopelessly illiterate in science. Providing for this literacy are outstanding teachers in ten outstanding programs promoting the teaching of Science as Inquiry. These ten programs provide good evidence and justification for saying, "teachers do make a difference".

OUTCOMES OF INSTRUCTION

Outcomes resulting from transactions were classified by Project Synthesis as being in four clusters: Personal Needs, Societal Issues, Fundamental Knowledge, and Careers. Each goal cluster was further broken down into components of doing, knowing, and attitudes (see Table 3 in Chapter One for a sampling of desired outcomes for students). These selected programs provide many examples of outcomes which exemplify The Project Synthesis Desired State.

Personal Needs

All ten programs are concerned with enhancing science literacy and developing personal traits of self-confidence, responsibility, and life-long learning skills. Most of the programs are individualized far beyond mere self-pacing and all programs show a high degree of flexibility. Their flexibility lies in a willingness to change topics, activities, or directions easily and quickly, allowing teachers to follow students and students to follow knowledge. This is in sharp contrast to more traditional programs where knowledge seems always to be pursuing the learner.

Some programs, such as Problem Solving in Physical Science in Imperial, Missouri, seem ready to drop all pre-planned notions to investigate problems which arise. Others, like the Research Science Program in Brevard County, Florida; Methods and Applications of Science, Easthampton, Massachusetts; Individualized Science Investigations, Sunburst, Montana; and Science Project Seminar, Phoenix, Arizona; have developed curricula which build in spontaneity and flexibility. Flexibility is an essential component of these programs since they all involve individual students working on independent research projects.

While these programs are certainly not unusual in emphasizing personal science, they also stress development of high level communication skills. Many of the research-oriented programs have highly structured curricula designed to foster students' ability to write, speak and present their research in the best way possible. Some even go so far as to involve faculty from English departments in teaching writing skills and drama teachers to coach students on presentations. Several video-tape student presentations which are later critiqued by the whole class, the teacher, and other knowledgeable professionals. These students are learning that **doing** science is only the beginning; they must **communicate** science before their task is done. In the process they are learning valuable communication skills which will aid them in whatever field of life they ultimately choose.

Student attitude toward science and science teaching must also be enhanced in these programs which promote independent decision making, thinking and management skills, and self-confidence. In viewing these ten programs we see schools where students are personally involved in examing their own environment in their own way with their own expectations. They are learning to do and communicate science in ways that make sense to themselves. These students are taking risks inquirying but in an environment made safe by supportive teachers, administrators, and communities.

We are seeing students who are science literate in the best sense of the word; students who are creative yet disciplined, students who are actively using science knowledge in making decisions and feeling their own motivations at work. These students are learning survival skills which will become increasingly more useful and necessary in our ever more techological and scientific world.

Societal Issues

While all ten programs use science related social issues during the year, some like, **Environmental Awareness**, devote a major portion of their year to this needed area of inquiry. Teachers in these programs are constantly alert for science class opportunities which easily relate to society at all levels. Some are very contemporary, focusing on energy isues, while others are following a more locally relevant approach. Almost all seem to emphasize the values and ethics inherrant in decision making and spend much time processing how decisions are made.

How science and its products benefit mankind is a key element in many activities and discussions. Aspects of economics, psychology, and sociology are ever present in some classrooms as these innovative science teachers work with students who are truly seeing science as a human (and therefore fallible) enterprise. Issues relating to growth and development of individuals, businesses, ideas, government, societies, and nations are now found in science classrooms alongside more traditional issues of environment, genetics, and technology.

Even those programs which are science project and competition oriented frequently find societal issues in their classrooms as students investigate problems relating to alcoholism and substance abuse, malnutrition, genetics, and stress. These students are using the processes and power of science and logic to delve into problems of society; truly they can be said to be doing social science in every sense of the word.

Students (and teachers) participating in such clases are learning first-hand the implications of science for society. They are seeing that decisions, even those based on science, are not value free; that even scientists cannot be above ethics and morals. Certainly we can say that students in such programs are likely to appreciate science as never before as they see how to use the outcomes of science in dealing responsibly with societal issues and problems. These are society's leaders of tomorrow as envisioned by Project Synthesis.

Fundamental Knowledge

Even those programs most emphasizing societal issues have not relegated science to the back seat, however. Learning science, and lots of it, is essential in the eyes of all these program developers. Where they differ, though, from many programs is how and when they expect students to learn and what they expect students to do as a result of this learning. At the same time, these teachers frequently have radically different standards of whether or not the learning has taken place.

Their students study the usual texts but neither trust nor rely on them. They actively inquire into the meaning and usefulness of what they learn; they are always questioning. In many of the programs students spend much time reading the research literature, learning for themselves how knowledge was gained. Their teachers want students to realize and value the hard work involved in discovery and to experience the thrill and excitement of new-found knowledge. Teachers further want their students to use this knowledge and excitement in making decisions, doing research of their own, and in furthering their own knowledge. To these teachers, science has not been fully learned until it can be applied to problems identified by the learner.

These teachers, rather than prescribing what must be learned and, having satisfied that goal, moving on, design learning environments where instruction doesn't end with so little meaning. These environments demand application of knowledge in identifying problems and use still more knowledge in actively seeking solutions. While intellectual curiosity is encouraged, as it should be, so are pragmatism and productivity encouraged. Students in these programs not only know how to gain knowledge but can apply and apply well that knowledge in a variety of scientific, personal, and social settings. Again, there are students who are well on their way to attaining literacy in science.

Some Notable Academic Achievements by Students in the Six Research-Oriented Programs Teaching Science as Inquiry

10	Winners, Westinghouse Science Talent Search
17	honors, Westinghouse Science Talent Search
32	place awards, International Science and Engineering Fair
3	Winners, Youth Science London Fortnight Awards
1	Winner, Tokyo cherry Blossom Festival trip
1	Winner, Trip to Nobel Prize Ceremony
5	Navy Cruise Awards
5	Winners, Regional Space Shuttle Contest
1	Winner, Edison-McGraw Award
2	Winners, Naitonal Energy Independent Research Award
7	Presidential Scholars Finalists
2	National Merit Finalists
22	National Merit Semifinalists

In addition, students from these programs have won thousands of regional science fair trophys and ribbons and more than $1,000,000 in scholarships for each graduating class each year.

Careers

While it is obvious that many students doing research are exploring careers as researchers it may be less obvious that some students are, at the same time, discovering for themselves that they do not wish to be researchers. Career or not, they all come to appreciate what science and research are and what researchers do. Even those who have no intention of embarking on science careers may well use their skills, knowledge, and understanding in whatever careers they eventually choose.

But, science research is, only one career among many promoted and modeled by the unusual teachers in these outstanding programs. One career being modeled well is of particular interest to us--science teaching. Their students are seeing science teachers as energetic, knowledgeable, ambitious, and highly professional individuals. Teachers are seen as caring, competent, and concerned for the welfare of their students, their communities, and society. This positive perception of teachers may well led to consequences well beyond students wishing to be teachers themsevles. These students will be leaders in their use of science and may eventually take positions influential to schools or school districts. Viewing teachers as professionals is a first and necessary step in enhancing the profession's overall status and desirability.

Most of these ten programs make liberal use of community resource person as classroom speakers, as mentors, and as experts to be learned from. Hearing and meeting with professionals provides additional career models whether they be farmers or pharmacists, fishermen or physicists. Students venturing out into the community, interviewing people at work, meet these resoure people in their home environment and gain powerful new images of alternative career paths. Some of the older students in the research science classes gain part time or summer employment through these community contacts; another stepping-stone on that same career path.

IN CONCLUSION

As predicted by the Synthesis Researchers, we find the teacher to be the critical factor in designing and creating an environment conducive to inquiry. The teachers in these ten programs are possessed with and by inquiry to the extent that their classroom reflect this possession. Their inquiry natures are contagious and they are eager to infect their students. To effect this innoculation, teachers carefully construct a learning atmosphere where risk taking is safe and acceptable, where rewards are provided for use of knowledge rather than regurgitation, and where issues are as important as facts.

The classrooms themselves reflect a well-used patina and, often, a lack of tidyness indicative of constant use and too many materials in too little space. Both the physical and intellectual environments are stimulating and the intellectual is as unrestricted as possible. The flexibility necessary for inquiry is reflected in both the physical arrangement of these classrooms and the attitude and behaviors of the teachers.

Project Synthesis suggested inquiry classrooms would reveal a variety of teaching methods but a consistency in teachers who valued learning, respected the ideas of others, and who served as role models of inquiry persons. We found this prediction to be amazingly accurate. These teachers are thorough and thoughtful in planning, executing, and evaluating their teaching. Most seem to be more concerned with **how** an activity is done than with **what** is done. all claim inadequate time but, while many more traditional teachers seek time to cover more chapters, inquiry teachers seek more time to further real student accomplishment, understanding, and reflection.

Some Generalizations

We find that excellent programs teach

* were designed to be excellent
* involve several years of deve
* are still evolving
* frequently make use of severa inservice
* do not place textbooks in a c
* involve a locally developed c
* have strong administrative an involvement
* have close ties with post-sec
* have highly energetic teacher in professional organizations
* have very current, knowledgea teachers who have rationales

Many features from these progr part. While no one feature way be add up to a very pervasive model and to students and teachers alike. By instituted in your program, will tra the teachers and developers of the environment they wished to create, y will lead to excellence in your own call, or visit any or all of these truly inquiry-oriented classroom env luck and extend our certainty that yc as we found provided by these program