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SELF-PACING PHYSICAL SCIENCE; A STUDENT CENTERED SCIENCE PROGRAM

by

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ABSTRACT

The purpose of this study and its resulting program was to design a course of study in science education for the younger secondary school student. Science education has an important part to play in the preparation of our students for functioning in society. As with other disciplines, the methods used to teach science have evolved historically as societal needs and educational research dictate the manpower and offer functional ideas for instruction. This study provides the rationale as well as the structure for a high school science program designed to put the student at the center of the learning process.

Self-Pacing Physical Science is a course developed for use in the Lake Mills Community School, Lake Mills, Iowa. The program combines the student freedom of independent study and the close guidance of individualized instruction. Students complete activity packets as their ability permits, within reasonable limits. The materials for the course are sequential, self-contained packets, which allow the students the choice of their activities for a given period of time. In this way, the learners can determine the daily sequence which best fits their own rate of study.

Evaluation is based on packet quality, laboratory activities, quarter test, daily performance, and individual projects. Grading processes are cooperative, with both the student and the instructor providing input for the final grade.

Indications of future developments for the program include further studies to determine the effect of the program on the self-image of the student and the construction of an instrument to expedite the alterations for more effective evaluation.
CHAPTER 1

INTRODUCTION

The time has to arrive when the American educational system confronts the responsibilities which have accompanied its function throughout its evolution from the pilgrim era to the present. At various times, the objectives of the system have ranged from an affirmation of conforming religious dogmas, to attempts to nurture individual differences within the system. Now, schools, instructors, and administrators have materials available for meeting the demands of the modern society; more and better guidance services, extended resource devices, improved media offerings, and increased selection of curriculum instruments.

While science instruction in the nation's schools has contributed to meeting the government's goals of putting men on the moon and the related advances in space technology, concurrent deficiencies in the program are requiring a closer look at the methods of instruction used to achieve these goals. Declining enrollment in elective science offerings and suspicions toward industrial and collegiate research motives indicate that contemporary, laboratory centered courses do not succeed in transferring the values of technology and science in our society to the learner.
The responsibilities delegated to science education in the present school structure place it at a critical position in the general curriculum. Most of the students in our schools aren't going to be the astronauts, engineers, and ecologists of the future. Yet, the responsibility of science teaching lies in equipping these students with the capabilities necessary for interpreting and evaluating the changes in our culture which are a result of space exploration, mechanization of the labor roles, and the impact of escalating contamination of the environment. As a product of science education, the student needs to be able to make decisions both of values and action which reflect a knowledge of the processes which surround him and effect his performance.

Conflicts and problems which arise concerning our educational complex are no longer presented and resolved around the hot stove of the general store. The rate of change in the real world has guided the school community to develop a new approach to the difficulties which confront the non-academic learner. Yet, as Broudy (1961) describes, the community is faced with mandatory achievement in the technical fields that our national educational-industrial system has established. Educators are urged to be
accountable for methods and rationale used in an attempt to meet the needs of change. This places the instructors in the position of seers, responsible for events which have not happened.

George Katagiri (1964, p. 45) leaves little doubt regarding the rate at which our knowledge is increasing, reporting 150,000 new research studies completed in a six month period. This volume of data can't merely be passed by in our educational process, for the increase in technical knowledge leads to the creation and deletion of vocations upon which the students livelihood will depend.

Teaching the learner what information is accumulating in our knowledge system is not possible nor, as Bruner (1966) affirms, can moving the technically competent student ahead at the expense of the less able or uninterested individual be justified. Moves to humanize education have called for developing each individual within their own frame of reference. Yet, when is the time available to accompany each student through the educational process? Students receive the feeling they are being manipulated against their will toward course objectives which are not relevant to their needs. This situation exists even when the course is supposedly structured to allow them the greatest lattitude.
Harold Wengert (1971) refers to this situation when he reports decreases in the enrollment for science courses nationwide, even after instituting the individualized programs which resulted from the National Science Foundation's Study Committees recommendations.

A method to achieve both of these aims, humanism and preparation for technology, can be realized by allowing the student to participate in all phases of their learning. Why not allow the student the decision of selecting what he perceives as important?

The problem of this study was to develop a course of study in physical science designed to put the child at the center of the learning environment. The problem included the formation of a self-pacing, packet, structure for the course which will allow each student to progress at his own rate within a framework of required, optional, and enrichment activities.

There are courses produced on the self-pacing concept available for use as elective senior high school science classes, best exemplified by Personalized Adventures in Chemical Education (PACE). Wengert (1971) has reported reversals in the downward enrollment, development of responsibility on the students' part for their own learning,
and expressions of chemistry being enjoyable which indicate that PACE is achieving the goal of being an interesting learning experience for the student. My study has generated a program which provides the opportunity for science to be as much fun, and as rewarding, for the student in the junior high as PACE has been in the upper level.

The question could reasonably have been asked, "Why develop a new science program when rather large sums of federal monies have been spent developing programs such as Intermediate Science Curriculum Project and the Inquiry Role Approach?" These programs have updated the ideas to be taught and placed heavy emphasis on involving the student in laboratory experiences. They also involved the student in the processes of science. However, these programs are still teacher oriented. They do not involve the student in the determination of what he studies.

Introducing the self-pacing program for the ninth grade physical science course involves orientation of the instructors who will be responsible for the classes. It requires preparation for fifty classes of one student, not two classes of twenty-five students each. After two years directing a PACE program, the writer is convinced that the greatest joy of involving the students with their own education also
introduces a time factor, the greatest limitation to the program. The program takes time, and students who are involved with learning grow impatient. To implement the program will require very careful planning and scheduling to allow access to the learners who desire help as well as guidance for the students who are being evaluated.

In a school preparing students for competency in a rapidly changing society, science should be designed primarily for general education. To achieve these designs, the course offers flexibility enough to provide in-depth experiences for the science prone student as well as to develop ideas that can be conceptualized by the less able learner. Reaching the interest of these less able students demonstrates the most important aspect of the self-pacing science course. For most of the students with lower aptitude or interest, the ninth grade physical science course will be their last science class. These students need problem solving experience where they feel success. If the instructor is constantly aware of the progress made by the student, he is better able to transmit feelings of accomplishment to the student, even of a small measure.

To assure the instructor frequent interaction with the student, sequential packets of moderate length which have,
as their unifying activity, questions to be answered based on laboratory activity or reference reading, are used. The characteristics of the program which differentiate it from the conventional science course are extremely close and active student-teacher relationships. Frequent contact on a one to one basis helps keep the student at the center of learning, which allows maximum development of each individual regardless of his background or intellectual abilities.

In an attempt to upgrade science instruction, curriculum advances in this area have shifted emphasis to the selected important concepts rather than content recall. There has been little regard for the development of positive attitude by the individual learner. The goal of this program was to apply methods which have been effective in elective science classes to a required course in ninth grade physical science. The program is designed to apply self-pacing approaches that help develop a positive self image for the student and provide a position from which the learner can view science in a non-threatening environment.

The remainder of this study is organized as follows: Chapter 2, is a review of the developments in science education which have led to the self-pacing concept; Chapter 3,
is an outline of the structure of self-pacing physical science including the form used in packet construction and evaluative criteria; and Chapter 4, presents some of the revisions prompted by the pilot program and indicates further analysis to be undertaken to improve the effectiveness of the program.
CHAPTER 2

RECENT EVOLUTION OF STUDENT CENTERED INSTRUCTION

The contemporary general science classroom has developed from the need for a nontechnical course which will introduce the student to the scientific processes which influence him. There have been, however, changes in the content and structure of the course. The references cited in this review describe the methods used in science classrooms. Primary emphasis, however, will be centered on the development of materials which can be used to aid the formation of attitudes toward science as a process, as opposed to describing the technical content. Further review is given for two government sponsored curriculum projects, and the self-pacing program which is being used for a model.

CHANGING DEMANDS ON SCIENCE EDUCATION

In the 1930's, the teaching of science followed a basic design of a content centered class where the student was required to learn facts and how to apply these facts to a given situation. Ekerhard & Hunter (1940) have reported on studies conducted to evaluate the effect of the teachers' approach regarding attitude development during this period. The study produced inconclusive results, since it was felt
that the instrument used was more of an aptitude test than an attitude evaluation. Science in the secondary school during this period was essentially a college preparatory exercise, emphasizing the rote learning material required for students who were specializing in the discipline.

The entrance of the United States into World War II had a marked effect on the teaching of science in the secondary school. Waid (1958) asserts that the need for technicians and engineers to direct the machinery for war production resulted in vocational guidelines and activities being instituted for the student in secondary science classes. After the war, the machinery was converted to domestic production, creating the need for more trained operators. Science classes responded by concentrating on the technical output. These results were most effectively achieved by lecture and confirmatory laboratory activities. Job demands were more than filled by this process.

Following the initial increase of trained people after the war, a steady decline followed as the need for more technicians became less critical. A decrease in the enrollment of students in elective courses indicated that the methods used for instruction were not adequate to maintain the enthusiasm of the student, according to Waid (1958). In
an attempt to remedy this situation, the government began to train teachers in summer enrichment programs. The specific results of these programs were not determined, Driegbaum and Rawson (1969) contend, as the Korean conflict caused an upswing in emphasis similar to the increase in technical job placement after World War II.

By the mid-1950's, Thurber and Collette (1968) indicate, science instruction had settled down to uniform curricula which emphasized the physical laws and the accepted facts, with the laboratory serving the function of reaffirming the facts presented in the text. Methods of making the course applicable to the students' future consisted of citing instances where the principles were used in industry and the home.

During revision of science curriculum in the years preceding and following World War II, the objectives showed a trend which moved away from imparting knowledge to an increased emphasis on the functional, problem solving, aspects of science. A portion of this move must be attributed to the need for war production and the resulting boom economy. However, the structure of science education was being influenced by the pressures and needs of a society which was progressing by leaps and bounds toward a
technological machine. Better methods of utilizing the processes of science as a means of preparing the student for a mechanized culture were needed.

NEED FOR REVISION

The increase of scientific knowledge was now reaching incomprehensible levels. Cooperative efforts between the previously discrete disciplines were resulting in information which could not be completely understood by a person trained in only one field of study. The implication of scientific progress and exponential technical growth regarding the structure of science teaching was beginning to come into focus. Teachers could no longer rely on their knowledge of the subject matter. Instead of using the body of knowledge as the objective, it was necessary for the student to develop the process of discovering the relationships and analyzing their discoveries. Or, as Hallmeyer (1958) states, the performance of cognitive exercises was no longer the primary obligation of science instruction.

Workshops and summer training short courses were established in 1953 by the National Science Foundation (NSF) which informed the instructors of new techniques and curricula available. Kriegbaum and Rawson (1969) describe
that, in these courses, demonstrations and actual participation in the techniques were used to acquaint the teachers with the process. The effectiveness of the workshops soon became evident as research on the new courses of study generated materials available nationwide.

McConnell (1964) reports increased availability of the NSF institutes provided by the federal funding for the space program and Title III of the National Education Act of 1958. Space technicians were needed to staff the machinery, and once again the school classroom was required to prepare the student for a technical position in industry. There was, however, provision in this proposal to show primary concern for the guidance and general education of students, as reported by Mullholland (1964). The subsequent effect of these teacher programs, and the technical push, was to accelerate the implementation of modern curricula in science education.

RECENT PROGRAMS

Formal, published, curriculum materials from NSF project funding were structured to allow the student to discover the principles and concepts related to the subject matter. The student now became an active participant in
the learning process. Abraham (1971) now described the desired objectives for the student at the secondary school. These objectives were to develop critical thinking on the part of the student and to present the minimum rote learning exercises, thus allowing the learner to construct his own body of knowledge from observation and interpretation.

Merrill and Ridgway (1969) reviewing the Chemical Education Materials Study (CHEM Study) project, an early example of the curricula fostered by the NSF, report that a steering committee organized to survey existing instructional materials for chemistry found they were deficient. Such courses, the committee felt, were: 1) overconcerned with memorizing a great deal of material that was out of date and/or relatively unimportant; 2) not emphasizing major unifying concepts and principles; and 3) devoid of meaningful laboratory work, having the student carry out cookbook exercises. They continue to report that in an effort to remedy these deficiencies, the committee sought to bring scientists and teachers closer in the understanding of science and to design a course which had appeal and interest, not only for the science oriented student, but for the terminal student as well.

A more recent study concerning the development of a
unified course of study for science at the junior high school level. The Intermediate Science Curriculum Study (ISCS, or Florida State Project, 1971) carried the student involvement in the learning process to the point where the teacher acts as a guide and evaluator. Pathways are provided for tailoring the sequence of activities to the needs of the individual. The result is a science curriculum which offers a chance for most schools to provide individualized science instruction at moderate cost and little teacher inconvenience. However, the outcomes are still fixed - there is not an independent course of study for the learner to follow.

THE MODEL

In the school year 1967-1968, another approach to science education was introduced by Harold Wengert (1971), at the University of Northern Iowa. A union of individualized and non-directive instruction, Personalized Adventures in Chemical Education (PACE) allows the student to make his study an experience as the learner's ability permits. With the student at the center of the learning environment, the major objectives are to develop responsibility for the student and to reawaken the feelings of
success which traditionally have been suppressed by recitation programs.

The student progresses through the PACE materials at his own rate, venturing into optional activities when interest or inadequacies warrant. Close teacher-student interaction keep the student aware of his progress. All criteria for earning grades or scores on activities are cooperative efforts, with the student and the teacher both providing input to the final decision.

SUMMARY

The literature affirms that science teaching methods in use today differ from those of past years in two major respects; the student is involved directly in the learning process, and the objectives of the course are moving away from the accumulation of factual knowledge toward an understanding of the place of science and its techniques in today's society. As curricula becomes more student centered, the instructor becomes less dependent on his body of knowledge and cooperates with the student to guide the growth of the individual.
CHAPTER 3

THE SELF-PACING PHYSICAL SCIENCE COURSE AT LAKE MILLS SCHOOL

This program was developed to replace a text centered ninth grade physical science class in the Lake Mills School, Lake Mills, Iowa. To meet the needs of the science requirements and still allow the students full latitude for designing their own approach to learning the material, it was decided to base the structure on sequential packets which present the activities in a self-pacing manner.

The use of a self-pacing approach means that the students are allowed to cover the material at a rate which lets them firmly understand the concept before they move on to the next one. This does not mean that the individual could spend an inordinate amount of time in a particular area, but, with personal instructor guidance, the learners can spend extra time on difficult material or pass over some activities which they already understand.

OVERVIEW

The structure of the self-pacing science course involves the student and the instructor performing frequent cooperative assessment of progress. When limits are defined leader can make decisions, both participants are more
The learning activities in this program are designed, primarily, to provide concept development with the content material presented as representative examples from which the students will draw generalizations.

The self-pacing curriculum defines the responsibilities of the learner and the leader, while offering activities which allow for growth within the conceptual framework of the course. Using packaged units, within which the student has latitude of content and time allotment, the course provides sequential learning activities tailored to each individual.

COURSE CONTENT

Competence in the program is based on performance in these seven sections or conceptual units:

I. Laboratory Techniques and Safety Procedures
II. The Structure of Matter
III. Chemical Reactions
IV. Energy
   A. Conventional
      1. mechanical
      2. thermal
      3. light
B. Technological
   1. electrical
   2. nuclear

V. Fundamentals of Ecology
VI. Man's Responsibility in a Technological Society
VII. Molecules Important for Life

These areas were chosen from the broader field of physical science because they allow an overview of techniques and scientific relationships, yet, still allow for a time frame which can accommodate self-pacing in the classroom.

STRUCTURE OF THE PACKET

In order to reduce the physical size of the materials the students use in the classroom, and to personalize the records the students collect, the above units are divided into packets. These packets progress from basic knowledge about the concept to application of the generalizations that the students develop.

The packet, itself, forms the backbone of the course, providing a self-contained study guide, notebook, and laboratory directory. Being the student's own book, it allows the individual to record experiences and views of science from his own frame of reference.
To provide uniform appearance for the packets, and continuity for the materials the students use, each packet follows a consistent progression from background information to transfer of principles.

The presentation of student objectives, listed in the form of performance or behavioral results, introduces each packet. This allows the students prior knowledge of what they are to be responsible for after completing the packet.

The second part of the packet is a preface designed to introduce the student to the societal and industrial aspect of the topic being studied.

Following the preface, preliminary questions and activities which acquaint the student with the concept and the skills necessary to investigate the process in the laboratory are presented. These are primarily open-ended questions which will give insight into the learners attitude and background for the topic being investigated. When the student has completed this section, the instructor can determine the readiness of the learner to actively begin collecting data.

A survey of laboratory activities which illustrate the principles under study is included as the fourth item in the packet structure. The number and difficulty of activities performed by the learner will be at the teachers discretion,
based on the learners responses to the preliminary questions.

After the teacher and student have agreed on the activities to perform, the student constructs and carries out the work plan. Learner-leader interaction is at a maximum during this section of the packet since the student is using the processes of science to investigate a problem. The data collected and recorded during the investigations will be the base for the analysis and interpretation which follow.

After the data collection, the pieces of information gathered in the laboratory and references are brought together in a logical form. Depending on the complexity of the material, data guides may be included to aid the learner in this area. Correlation of the data analysis to the development of the concept follows as the seventh part of the packet structure. In this section, the student is again responding to questions designed to enrich his present knowledge and understanding.

After the student has successfully developed the generalizations of the topic, interpretive exercises are included which necessitate that the learner transfer principles demonstrated in the investigations. These are real world situations which require the application of concept elements developed by the student.
Preceding the formal evaluation of the packet, a review is included. The optional activities, references for enrichment, and a self-check test (with answers) which are a part of this review familiarize the learner with the expected performance for the packet.

A performance test, based on the initial objectives of the packet, completes the student's activities within the body of the packet. This test is mainly multiple-choice, with one or two questions requiring a brief laboratory exercise to gather data before responding. An eighty percent score is required and the test can be retaken until this level is achieved.

By following this format, the student is able to begin his study of the material with close teacher supervision. As he progresses through the packet, the activities become more and more removed from instructor control and the student is on his own to generalize the relationships observed during the activities. A sample packet from the structure of matter is included in Appendix A.

THE TEACHER INITIAL

The self-pacing course, which includes no large group lecture situations, requires close learner/leader
interaction. Much of this is accomplished while the students are at work in the laboratory or completing responses in their packet. To have immediate evaluation, and to reduce the bookkeeping required by the instructor, teacher initial boxes are included with the body of each packet.

At these points, the teacher examines the learners' materials since the last check and comments of the form of the student's responses - often asking questions which help clarify student's understanding of the activity. The instructor then initials a box provided to show he has reviewed the student work to that point. These devices allow both the evaluator and the learner an opportunity to check progress without removing the materials from the student.

The "TI," as the students soon come to know it, serves the even greater purpose of encouraging a one to one conference on a nearly daily schedule. This keeps the instructor aware of the student progress and can help identify the weaknesses and strengths of the student immediately, thereby reducing frustrations and misunderstandings without an extended lag time. The instructor also can perceive patterns of difficulty for the student and initiate remedial measures when surveying activities for the learner to follow.
THE PARTNER INITIAL

Another device which evolved from the student reaction to the "TI," is the "PI" or partner initial. During the first use of the program (school year 1973), the availability of the instructor to initial the "TI's" was found to be insufficient. Many times, necessary checks of one student's progress removed the instructor's attention from another student who was having a more immediate or serious problem.

One measure undertaken to alleviate the 'logjam' effect was to have the student, when in times of imminent collapse, use the call "Hey, Instructor" to indicate their need. The reply by the teacher was to respond to this call as a first priority.

A technical change in the structure of the program, the partner initial (PI), has shown good results acting as a built in item to reduce the long line of students. Initialing the activities important, yet not critical, for the development of the concept under study can be done by other students.

In these instances, where the material involves recall of past relationships, or the performance of a directed activity (e.g. mathematical computations or chemical
formulae), the student's partner or a seemingly informed class member can be consulted and asked to initial the "PI." In these situations, both the learner and the signee are responsible for the process involved and the subsequent performance of the learner. Examples of both the "TI" and the "PI" are included in the sample packet in Appendix A.

**EVALUATION**

An integral part of any course of study is the process used to evaluate the learner's progress. Moves toward individualization have presented a challenge to formal structure in an evaluative instrument. Criteria established by unit or lesson objectives can be tested in a direct manner (a test or oral quiz), but the products (outcomes) of the self-pacing study embody a broader range of growth than just the cognitive performance.

The breadth of development desired with this program requires daily observation of how the learner feels about his own progress. Important questions to ask while watching the students include behavior judgments. In what manner does the learner express himself? How does he interact with other students and his instructor? Is he responding from desire to learn or just carrying out perfunctory exercises? Would the
student be better off at some other activity at this time? If the instructor keeps this type of question in mind while leading the students, then the growth of the individual learner will be considered along with the content material.

The student provides input for the evaluation scheme, as well. For each packet, the learner evaluates his own performance in terms of: 1) depth of understanding, 2) self-discipline and use of time, 3) laboratory performance, and 4) clarity of expression. The absolute score value of these areas aren't nearly as important in judging the learner's success as is the integrity with which they evaluate themselves, and whether an objective inspection of the score sheet shows progress as a function of time.

Within each of the four areas, the student receives a criterion sheet describing what attitudes and behaviors are deemed necessary for a particular level.\(^1\) When the packet is completed, both the student and the instructor complete a profile of the four areas for the student, plus the score for the performance test. Before the score is entered as a permanent record, the student and instructor meet to discuss

\(^1\)A copy of the criteria for laboratory performance is included in Appendix B. Criterion sheets for the other areas are available from Lake Mills School.
the accuracy and objectivity of their individual score values.

Further conference time involves reviewing the student packet and checking for completeness of the teacher and partner initial boxes.

Grades for the course are computed from the packet score, the score on a nine weeks exam (including both written and laboratory sections), daily performance (one point per day that the student worked), and any outside research or extra credit the student did. In this manner the portion or the student's evaluation attributed to a test score is equal in weight to the other areas. Reduced grade emphasis on a test score tends to reduce the threat, especially for science shy students. Inclusion of a student assessed daily performance score keeps the learner aware of their activities.

SUMMARY

Self-pacing physical science involves structuring the materials and classroom arrangement to make best use of the student's own abilities. The self contained packet construction allows the student to complete the activities and evaluation with maximum teacher assistance. Initial boxes
at regular intervals assure that teacher aid is available where the material might be confusing or difficult.
CHAPTER 4

REVIEW OF PILOT PROGRAM

The primary rationale for designing this program developed from a need to offer the students a more rewarding experience in science during their early secondary school years. Since programs available either had their basic reliance on text centered activities or required too great an outlay for materials, it was decided to produce a new course of study. As an interim course, Interaction of Matter and Energy (Rand McNally) was implemented. The activity centered material used in this science course fit the basic aims we were working toward and the equipment was relatively inexpensive.

Initial development, to break the lock-step assignment format, included the writing of study guides which offered the students options for daily activities as long as the material was completed within a prescribed time period. During this stage of development, the student's records and reports were checked and evaluated after the papers were handed in.

When the self-pacing materials were ready for introduction, the evaluation procedures were instituted and the program presented to the students.
The alteration of the internal evaluation which led to the use of the partner initial is an example of the revision done in response to student feedback. With continued use of the program, there will be further revision of the program to increase its effectiveness.

The basic guidelines to be followed when a revision is suggested must adhere to the structural outline of the program (see Structure of the Program, Chapter 3). In addition to instituting the PI, new or future features planned for the program are described below.

INCREASED USE OF RESOURCES

Many students felt the program removed too many of the traditional ways of gathering information. Items such as question blocks from a book, single topic lectures, post laboratory discussions, and pre-test review sessions were mentioned by students for filling the need. In order to retain the students' responsibility for forming the generalizations, yet allowing them access to more specific information about a topic, more extensive use of the reference reading and followup evaluation by the teacher will be required (see sample packet, Appendix A).

Other resources, not extensively used at this time,
are the various forms of instructional media. Slides, filmstrips with dialogue, and the single concept film-loops are presently being viewed for added integration into the program where their use will increase the effectiveness. Plans are being made for further implementation of these materials during this coming year.

PACKET LENGTH

As the program is now constructed, the length of time necessary to complete each part varies from three days to over two weeks. These longer packets, although still covering a single principle, often create a stress. Students tend to slow down and lose the continuity as the time spent on the material increases. Also, as the length increases, so do the number of activities and skills. This presents difficulties for evaluating the student's performance by testing.

Reducing the length of the longer packets, or dividing them into smaller sections, will aid the overall evaluation of the student. By allowing more frequent packet evaluation, the student would receive more direct teacher comments for the expression and use of time areas, especially where much improvement can be achieved through a conference.
NEW ACTIVITIES

The energy units, now mostly keyed to textbook activities, need to be developed into packet form, providing more continuity in the latter part of the program. Further work is needed in the ecology unit, also, to better integrate the field activities with the laboratory and research conducted in the classroom. In addition, plans are also being made to include values level activities within the framework of each packet to allow the students an opportunity to relate their feeling and opinions to the context of the classwork.

Student research, either of a project or long term study format, will be required on a trial basis. When the course was on a structured time basis, a science project was part of the activities and, for the majority of the students, the only opportunity to apply science processes. The experience of starting from scratch on a problem, and the personal involvement in choosing the topic, merit the retention of this activity in a self-pacing course.

QUALITATIVE REPORT

One of the advantages of conducting a pilot program before reporting on its many facets is the opportunity to see the students interact with the materials. Preliminary,
non-statistical returns from the students indicate that some aspects of the program, discussed above, need alteration to better serve the learner. The areas needing revision were mostly in the evaluation scheme, and it is here where the attempts to integrate student involvement have created the greatest need for flexibility. It is most fervently hoped that the classroom atmosphere will continue to prompt honest and frequent student feedback on how the course feels to them.

What's good with the course also flows back from the students. The opportunity to work at their own pace, choosing the intensity of involvement on a particular day, and the reduced emphasis on formal homework assignments were overt expressions by the students. By its very nature, self-pacing encourages a very informal student-teacher relationship. This aspect of the course probably was the most evident in the day to day classroom activities. The students feel free to discuss openly with the instructor, often on topics not concerned with packet materials.

RECOMMENDATIONS FOR FURTHER STUDY

Significant study remains to be performed to determine the effect of self-pacing on the responsibility and self-concept of the student. With refinement of the evaluative
scheme used for the course, it will be possible to construct a profile of attitudes which the student expresses. An instrument to determine the improvement of student responsibility is being readied at this time for pretest and post-test application.

Further data collection and analysis to determine the correlation of student score and teacher score during the packet evaluation will be conducted. This will offer a more confident basis for deleting, adding to, or modifying the items of the evaluative process. Putting these criteria for change on a significance level will allow a smoother revision of format and reduce the trial time necessary to verify new items.

When the structure of the self-concept instrument and a reliable internal revision technique are completed, then the self-pacing physical science course can be used with full confidence that the student is receiving the full benefit of its design. With the students at the center of the learning process, their education can take on personal and rewarding perspectives not possible in other contemporary science courses.
The Old Shell Game
or
Here a Peg, There a Peg

PURPOSE:

After completing this unit you will be able to describe an element in terms of the electron placement in the atoms and to recognize similarities in the structure of certain groups of atoms. You will also become acquainted with the use of the electron board and learn how to determine the electron structure by just knowing the atomic number.

The reactions you have witnessed in the previous packet are examples of a few of the types which chemists have classified. These groups are constructed to reduce the total reactions which the scientists need to remember in order to notice what is going on.

Look back on your notes from ISM #2 and see if you would classify any of them as physical reactions. What questions do you ask yourself before deciding that a reaction is a physical reaction?

Again refer to your notes from ISM #2 and see if, from those you have classified as chemical reactions, you can identify two or three distinct types of reactions. Name these general classes, identify the reactions and describe why it should belong to the class where you have placed it.

I Type 1 reactions:

II. Type 2 reactions:
III. Type III reactions:

T.I.

Perhaps some of the criteria you used for classifying the various reactions were visual: or possibly you used other senses to determine how the phenomena were similar. Yet, even though we can sub-divide the reactions in this way, maybe the most important division you made when classifying ISM#2 was when you decided to name it either a chemical or physical reaction. Somehow, these reactions we have classified as chemical all have something in common. Our basis for determining this, so far, has been appearance— but even physical reactions cause a change in appearance (although short lived or of a non-permanent nature).

A deeper understanding of what happens during a chemical change can be obtained by looking beneath the observable descriptions. The existence of the sub-atomic particles was studied in ISM#1. Name and describe these particles in the following spaces: (work cues; charge, mass, position)

1.

2.

3.

P.I.

Only one of these particles is active during a chemical reaction. From the placement of the particles in the atom, which of the particles do you think takes part in the reaction? Think about this particle as you carry out the following reactions. See if you can collect the type of data that will help you design a model of the atom that describes and accounts for what you see.
REACTION #1

Materials needed:

- 16 cm strip of aluminum wire
- 10 ml of 0.10 M Pb(NO₃)₂
- 1 medium sized test tube

Obtain 10 ml of lead nitrate solution and place it in a medium sized test tube. Bend a 16 cm length of aluminum wire so most of it is immersed in the lead nitrate solution. Carefully describe the reactants in this reaction:

Set this test tube aside for the present time but continue to observe what is happening while you carry out the next reaction. Record any changes you observe.

REACTION #2

Materials needed:

- 7 cm strip of magnesium (Mg)
- laboratory burner
- goggles
- forceps
- asbeston gauze (the one with the funny paper)
- hand lens

Obtain the materials and set up the laboratory burner. Polish the Mg ribbon with a piece of steel wool. Install goggles in accepted position. Light the burner and pick up the ribbon with a forcep and hold it in the hottest part of the flame until it ignites. After ignition, hold the forcep at arms length for the duration of the burning and concentrate looking in another direction. When the flame is out, put the ashes on the asbestos portion of the gauze.

What is the appearance of the Mg ribbon before ignition: ___
How do you account for the brilliance of the flame as magnesium burns?

Carefully observe the residue on the gauze. In what way does the residue differ from the initial reactants?

Remember to check the aluminum wire from the last investigation.

T.I.

Somehow, as is often the case, in a laboratory, we have observed a change. These are not earthshaking changes—nor are they new ones, yet they point out events that are the focus for an experience in science. Something happened that caused a change in the properties of a material.

The next step in the process of investigation involves determining why the change took place. By probing deep into the structure of matter you will be able to propose a model that accounts for the different appearance of reactant and product in a chemical reaction. However, you will need additional tools to perform this probe. These tools are of a simple nature, but they will help you visualize processes which no one has ever seen.

You have followed the development of the nuclear model which Rutherford proposed. Further study has revealed more information which allow more specific description of electron structure. The electron board allows up to peg down the planetary model.

The Electron Board:

This tooltoy is to aid you in understanding the placement of the electrons in the atoms of an element. It will also be of help in visualizing what happens during a chemical reaction. As with all models, limitations are present which will be mentioned shortly.
Obtain a board and notice that at the bottom are 20 "electrons" of different colors. These colors correspond to the shell that the pegs will be put into. The diagram above the pegs is a model of what a portion of the atom might look like. In the lower left corner of the model is a blackened area which represents the nucleus.

Working outward from the nucleus are circular lines representing the electron shells (energy levels). On these shells are positions where the peg electrons for that level can be placed. The red pegs represent the first group of electrons, those which occupy level 1. Likewise the second level is represented by the orange pegs, the third level by the yellow pegs, and the fourth level by green.

Keep in mind that the model is incomplete; to conserve space and keep the model easier to work with, some of the electrons that could occupy the third and fourth levels have been omitted. Actually the capacity of the third level is 18 and that of the fourth level is 32. Also, sophisticated investigations have indicated that the shells for the electrons more nearly resemble the skins of an onion. Keep in mind the nature of a scientific model while working with the electron board.

How to Use the Electron Board:

To make the best use of the board, you should refer to the atomic number of an element. As this number represents the number of protons (positive charges), the atomic number also determines the electrons (negative charges) that you will place in the energy levels. A good rule when using the board is to place a piece of paper under the corner so you can keep a record of the number of protons in the nucleus. To get an overall view of the particles you should record, in addition to the atomic number, the atomic weight of the element and the number of neutrons in the nucleus. In this way, after you have "put the electrons in their shells" you will not only have a model of the electron structure of the atom, but an idea of what is in the nucleus as well.

Using Boron as a sample, let's work through an example of how the board can help you.
BORON:

Atomic number = 5
No. of protons = 5
No. of electrons = 5

Atomic weight = 11
No of neutrons = 6

The atomic number, atomic weight, number of neutrons, and the symbol for the element should be placed on a piece of paper near the nucleus part of the board.

Since there are five electrons you should select 5 pegs; 2 red and 3 orange. The two red pegs should be placed in the level representing the first shell and, as can be seen, fills the spaces available. The three orange pegs go in the second level.

If you have not already done so, complete this example for Boron on your board. Take a look at the board and the information you have provided about the nucleus. You know the element, its symbol, its atomic weight, the atomic number, the number of electrons, and how the electrons are arranged in the energy levels of the atom.

Only three of Boron's electrons are in the outer shell. These electrons play a very important part in chemical reactions, so important, in fact, that we have a special name for these outer level electrons. Electrons in the outer shell of an atom are called VALENCE ELECTRONS. These valence electrons are the only electrons that take part in ordinary chemical reactions.

1. When the board has been filled in for a particular element, what information is recorded?
2. How many electrons can the first level contain? __________
   How many can the second level contain? __________
   How many electrons would a magnesium (at.no. = 12) atom have in its outer shell? ________________.

3. How did you determine the number of electrons in the outer shell of magnesium? ______________________

4. Explain why valence electrons are of special importance. ________________________________

5. Set up an electron board for sulfur and have your teacher check it.

T.I.

For a particular element an electron shell diagram can be shown. The electron shell diagram for magnesium is shown below.

```
12p+ 2e⁻ 8e⁻ 2e⁻
12n°
```

The 12 p⁺ indicates the number of protons in the nucleus, the 12 n° represents the number of neutrons in the nucleus, and the 2⁻8⁻2 show the placement of electrons in the shells.

An abbreviated form of this diagram, termed the modified electron shell diagram, for magnesium is shown below.

```
12p  K=2e⁻  L=8e⁻  M=2e⁻
12n
```

In this form the + and o have been deleted from the proton and neutron, and instead of arcs to represent the shells letters are used. K represents the first level, L the second level, on out to Q for the seventh electron level.

Using your electron board to determine the placement of electrons, complete the shell diagrams for the following elements. The atomic number and atomic weight are given.

Potassium – K at.wt. = 39; at.no. = 19
From the shell diagrams which of the above atoms would tend to gain electrons? Why?

Which elements would tend to lose electrons? Why?

---

REVIEW AND SELF-CHECK

1. Study all questions and your answers carefully. If you think of different ideas or better answers, change your paper to make it thorough, complete and understandable.

2. Check and compare your answers with those on the answer key. If your answers are complete and correct, mark each item with a "C." Return the key in at the end of each period. If you have incomplete or incorrect answers, do the following:
a. re-read the information and questions
b. re-do the activity. Think about why and/or how the sample key answers the question. Be sure that YOU understand the idea.
c. change your answer as necessary so you can mark it with a "C."
d. aim for understanding

3. Re-read, study, and think about the title, each question and each answer on your packet.

4. Ask your teacher for the mastery test. Complete the test within one class period.

5. Your teacher will score your test immediately and mark the score. Your answer sheet will not be returned. Your teacher will also initial the page if it is OK for you to go ahead.

6. If you are not satisfied with your mastery test score, study and re-take the test on some other day.

7. If you and the teacher are satisfied with your mastery test score, complete your self-evaluation in pencil and place your packet in your folder and then put your folder in the file "to be evaluated."

   OK for answer key

Test Score

   OK to go on to next packet
APPENDIX B

EVALUATION OF STUDENT'S LABORATORY PERFORMANCE
EVALUATION OF STUDENT'S LABORATORY PERFORMANCE

1. You require constant guidance. You cannot set up an experiment, take measurements, discern what data is desired and you have to rely upon other students for this information.

2. You require occasional advice. You can make observations and measurements but not necessarily in a systematic fashion. This may be due to a minimum of preparation or poor understanding of the experiment.

3. You usually can formulate generalizations based on observations of phenomena and data. Your work indicates some pre-planning, but you are not yet able to formulate a complete design for an experiment.

4. You understand the uncertainties inherent in observations and have a mastery of all techniques of observation. Because of adequate planning, you are able to recognize experimental problems and solve them without teacher assistance.

5. Your adeptness at experimental design enables you to develop innovative solutions to laboratory problems. You have presented suggestions which could result in a redesign of standard methods. You fully understand the relationship between that which is accomplished through experiment and generally accepted theory.

Similar criteria are used in the following areas.

A. Evaluation of student's communication of ideas and principles

B. Evaluation of student's effectiveness

C. Evaluation of student's knowledge of subject matter
APPENDIX C

STUDENT SELF EVALUATION FORM
REPORTING PERIOD:  1st  2nd  3rd  4th

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LITERATURE CITED


