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ABSTRACT

In addition to a summary of the proceedings of the Callaway Gardens Conference attended by selected science educators, scientists, and psychologists, invited papers by Robert Gagne ("The High School Science Program--A Psychologist's Assessment") and Clifford Swartz ("The High School Science Program--A Scientist's Assessment") are printed in full. The preliminary working paper, by Ernest Burkman, James DeRose, and Clifford Swartz, and summaries of the three working groups of the conference are also included. The conference concluded that the present high school science program, with its relatively uncorrelated and inflexible sequence of biology, chemistry, and physics is not suitable for the majority of high school students because it tends to overemphasize "pure" science and neglect the social implications of science and technology. Conferees agreed that a totally unified program, designed to cross traditional subject boundaries and include materials from more areas of science, including social science, should be introduced. To increase flexibility to cater to individual differences in interests and abilities, a three-year program based on one- to three-week relatively independent units was recommended. This would also allow science to be seen as a subset of a total educational program. (Several pages may be light.) (AL)

Final Report

The Callaway Gardens Conference on Building a Multiyear, Multidisciplinary, High School Science Program

October, 1971

Conducted by
The Florida State University
with the support of
The National Science Foundation

FINAL REPORT

CONFERENCE ON BUILDING A MULTIYEAR,

MULTIDISCIPLINARY, INDIVIDUALIZED

HIGH SCHOOL SCIENCE PROGRAM

FOREWORD

For some time Dr. James DeRose, Marple-Newtown, Pennsylvania school district; Dr. Clifford Swartz, Physics Department, State University of New York at Stonybrook; and I have been discussing our mutual concern with the present status of high school science teaching. During these discussions, the three of us reached agreement that something should be done to make it convenient and possible for schools to implement a significantly different type of science program from the one that is currently in vogue. Some of our ideas as to the nature of such a program appear in the working paper that was prepared later by the three of us for use by the Callaway Gardens conference. These ideas were also included in a proposal submitted by me to the National Science Foundation for funds to convene a broadly based group of authorities to consider the feasibility of developing the kind of science program that had been discussed. Once that support was obtained, Jim DeRose, Cliff Swartz, and I jointly planned what ultimately became the Callaway Gardens conference. The three of us also worked cooperatively on this final conference report, but, since I was most directly responsible for preparing the report, I must accept the responsibility for any errors of omission or commission.

Ernest Burkman
Conference Director
Florida State University
January, 1972

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The work reported herein was supported by the National Science Foundation. However, the opinions expressed do not necessarily reflect the position or policy of the National Science Foundation, and no official endorsement should be inferred.

"The time has come to design curriculum materials for the schools of the future." During three days at the end of October, 1971, thirty people gathered at Callaway Gardens in Georgia to consider the validity and possible consequence of this statement. They had come in response to an invitation sponsored by the National Science Foundation and issued by Ernest Burkman, James DeRose, and Clifford Swartz. The participants had received in advance a working paper which analyzed the present situation in high school science teaching and which then proposed the development of modular, multidisciplinary instructional materials suitable for individualized instruction. This report describes the conference and the conclusions reached, which went considerably beyond the relatively modest recommendations of the working paper.

The Participants

A complete list of the participants and their professional affiliations is given in Appendix I (green section). The group represented a very wide range of experience in science and school instructional materials development. There were one or more university chemists, physicists, biologists, physicians and economists. There were people who had played active roles in the development and spread of PSSC physics, CHEMS chemistry, CBA chemistry, BSCS biology, ECCP engineering, ISCS junior high science and AAAS and QS elementary school science. Every branch of the teaching profession was represented including classroom teachers, science supervisors, school administrators, professors of science education and learning theorists. We also had representation from various professional organizations such as National Science Teachers Association, Social Science Education Consortium, Council on Physics Education, the American Institute for the Biological Sciences, and the AAAS Commission on Science Education.

Most of the participants have played dual roles in the past so that regardless of their main affiliations they were familiar with school problems and the accomplishments of instructional materials development during the last decade.

The Working Paper

The full text of the working paper is given in Appendix II (canary section). It was expected that the conferees would use the paper only as a base for elaboration and revision. There are two parts to the paper, one consisting of general statements about the present school science problems and about the nature of the proposed modular materials, and the other containing more detailed plans for a particular proposal for preparing new materials.

The criticism of our present science teaching is embodied in five specific charges. These are followed by nine features that should characterize any new high school science program. The heart of the proposal is the call for the preparation of many short modules constructed so that a student can be more responsible for his own learning. These units were not described as forming tight sequences of study in biology, chemistry, and physics but rather as encouraging multidisciplinary work, perhaps with themes of social interests.

The details of the second part of the working paper were included to show one particular way in which the curriculum could be produced and packaged. It was assumed, correctly, that these details would be most subject to revision by the conferees.

Conference Sessions

The first day of the conference was devoted to position statements and organization. Ernest Burkman welcomed the participants and explained the background considerations that had led to the writing of the working paper and to the calling of the meeting. Robert Gagné then gave a paper entitled, "The High School Science Program -- A Psychologist's Assessment". This paper is included as Appendix III (blue section). After a review of the accomplishments and disappointments of previous curriculum revisions in the sciences, Gagné emphasized needs for the future. In particular, he called for attention to the overall goals of science instruction, for clarity in thinking about objectives, and for early and continuous concern about the system of delivery and the mode of instruction of new materials.

The conference next heard from three men who administer science programs or curriculum developments in three large school systems -- Washington, D. C., Shawnee Mission in the suburbs of Kansas City, and Miami, Florida.

Reuben Pierce, Science Supervisor for the Washington Schools, described the extent to which the new science programs are actually being used in his city. He called for greater attention to the daily needs and interests of the majority of students. The new science programs have had little lasting effect in most of his classrooms. Leonard Molotsky from Shawnee Mission, Kansas told of his system's efforts to individualize instruction for schools where the great majority of students go on to college and where parent interest and participation in school affairs is high. Molotsky reported that the system has produced a considerable quantity of modular material. Finally Richard White from the Dade County Public Schools stressed the political and financial realities of making changes in our public schools. In Miami they have instituted real changes in instructional systems as a by-product of such projects as reorganizing their schools for year-round use in five blocks of nine week periods. Dr. White stressed that local efforts of the kind in which his system is engaged are severely limited by the kinds of instructional materials now available. He specifically cited the need for modular learning materials and for carefully constructed sets of objectives and evaluative materials.

After lunch Clifford Swartz gave an assessment of school science teaching from the viewpoint of the scientist. He pointed out the very great changes that had actually taken place in school science courses during the past decade, but claimed that further advances can be made only by drastically altering the nature of the schooling process. His paper, which emphasized the power of modular, self-teaching materials to change traditional methods, is included as Appendix IV (goldenrod section).

James DeRose spelled out the problems to be faced in the conferee's discussion of the working paper and in any consideration of new teaching methods. He announced the division of the conference into three working groups, each with a chairman and recorder. Two of these groups were to concentrate primarily on the content and goals of any new high school science teaching program. The third group was requested to focus its attention on the nature of the materials themselves, including the problem of how the materials might be produced. The three groups met separately on the second day and reported their conclusions the following morning. These reports are included as Appendix V (pink section). The final morning session concluded with a discussion of the reports and the implications of the mandate to pursue an instructional development project that was issued by all three groups.

Summary, Conclusions, and Recommendations

The conferees were selected on the basis of their reputations, experience and affiliations and not because of any known bias on their parts in favor of changing our educational system. It is noteworthy, therefore, that all three discussion groups generally affirmed the critical analysis of our present schools that is given in the working paper. A summary of that analysis edited to reflect some of the points made during the conference is given below:

(1) Because science teaching is mostly group centered and teacher directed, few provisions are currently made for the variations in prior knowledge and experience, in interests, in ability, in learning rate, and in learning style that are known to exist among students.

(2) For many if not most students, the present science program tends to overemphasize "pure" science at the expense of applied science and technology. Furthermore, the social implications of science and technology are, for the most part, ignored in most science programs. These tendencies are in conflict with the fact that today's students live in a world that is dominated by technology and social conflict.

(3) There is little correlation between the biology course taught presently at the tenth grade level, the chemistry course taught in the eleventh grade, and the twelfth grade physics course. Furthermore, the validity of the present biology-chemistry-physics sequence is questionable and it is indefensible for a modern high school science program to be limited to these three science content areas.

(4) Existing high school science instructional materials tend to be inflexible. They incorrectly assume that every teacher and every school can and will offer the same content scope, and sequence, and will adopt the same instructional strategy. Furthermore, because the present materials were designed for use in year-long courses, they require that students and teachers commit themselves in advance to a particular sequence of topics for a full year. Although innovative teachers can, with difficulty, adjust their use of the materials to permit a more individualized method of instruction, the large number of American high schools that are now attempting to free their students from the course complex are severely limited by the type of instructional materials presently available.

(5) Few present science programs deal effectively with the problem of defining instructional goals and determining the effectiveness of instruction. This means that there is presently no way to meet the legitimate requests and in some cases demands of interested parties for an accounting as to the effectiveness of science education.

(6) The high school science curricula of the 1960's have failed to significantly increase the percentage of students who receive science instruction. Most of today's high school graduates have not received an adequate general education in science.

A Science Program for the 1970's

There was also general agreement that the most fruitful way to begin to make the adjustments that are needed, would be by developing and making available to schools a set of second generation instructional materials that would incorporate a fresh look at both the kind of science that high school students should study, and the instructional procedures that should be used in teaching high school science. Some of the features that the discussants felt should characterize such a new high school program are as follows:

(1) A total unified instructional system should be designed that would provide interesting and useful work for all students for all the high school years.

(2) The total set of program units within the new system should deal with a balance of basic and applied aspects of not only chemistry, physics, and biology, but of other sciences as well including the social sciences. Many, if not most of the program units should cross traditional barriers of discipline so that they would cease to be identifiable as dealing exclusively with chemistry, or physics, or biology, or with science at all for that matter. Units within the system should often emphasize real-world problems connected with human and social interaction and many topics should be drawn from the applied sciences and/or engineering.

(3) A minimum level of scientific literacy and capability for high school graduates should be defined and spelled out in advance. The instructional system should include learning activities that are aimed at helping students to reach these minimum levels. It should also provide a means for assessing progress toward these goals.

(4) The system should permit considerable flexibility of choice as to which instructional goals beyond the minimum ones that a given student should be expected to achieve.

(5) The basic unit of the new system should be considerably shorter than the one-year courses that now serve as that unit. A flexible three-year program composed of distinct one- to three-week program units would appear to have many advantages. Such an arrangement would make science study flexible in terms of topics, sequence of topics, individual pace, and depth of commitment.

(6) The program units within the system should be made as independent of each other as possible (complete independence did not appear to the conferees to be desirable or feasible). It should be possible for students, teachers, school districts, and states to order the program units in different ways so as to accommodate differences in student background, interests and ability, teacher preference, and local conditions.

(7) Each program unit of the new system should provide more than one way of working towards whatever common goals are desired. This kind of variety could be provided by the use of different media, varying reading levels, or even different conceptual approaches. For example, the same scientific phenomena can often be studied equally well through mathematical abstractions or through pictorial or physical models.

(8) The program units within the system should be developed in such a way that students can do the learning activities in them at different rates dependent upon their abilities and interests. This means that the materials must be designed for use on an individual student basis with the guidance and assistance of a teacher.

(9) In addition to the program units the new instructional system should include a flexible instructional management scheme that will assist school systems and teachers in choosing and implementing a new science program. At a minimum such an instructional management system should include the following:

(a) Alternate suggested ways to sequence the program units, i.e. different possible tracks for varying types of students.

(b) Suggested procedures for organizing and controlling any laboratory equipment or other things for student use that the units call for.

(c) Suggested procedures for assessing, monitoring, and reporting overall student progress.

(10) The cost to the schools of the proposed system should not exceed present expenditures for science instruction. For the most part, the program units should not call for large outlays of funds for new equipment or for new facilities unless equivalent economies can be made elsewhere.

The most important new direction to come out of the working sessions was a clear call for an expansion of science into the realm of everyday student life including the social science and mathematics. (See point (2) above.) The detailed plan in the working paper is almost conservative in this respect. To those who wrote the paper it seemed best to move slowly so that most of the new materials would be clearly recognizable as physics or chemistry or biology and thus could be easily used in standard classrooms. The conferees urged otherwise. They felt that many if not most of the units should be centered on themes of immediate, practical interest, involving elements of the standard science disciplines as needed.

Most of the participants agreed that any new high school instructional materials should be designed for the majority of students and not for the academic elite. There were differences of opinion about whether common materials would reach everyone or whether an attempt should be made to produce suitable variations for everyone. Fortunately, one of the virtues of modular materials is that it is possible to produce and try units individually without committing the whole effort to a particular approach or level of difficulty.

Science in the School of the Future

One concern that was expressed again and again during the Callaway Gardens Conference was that any future high school science program must be considered as a sub-system of the total educational system rather than as a separate entity. The conference participants emphasized that any steps taken to improve high school science instruction should be planned such that they are compatible with and contribute to total high school reform.

One of the advantages of a modular type of high school science program is the fact that such a program could easily be merged into an overall scheme for upgrading the entire high school. The modular approach that has been suggested could be converted into a total instructional system simply by developing additional program units that deal with content from other areas of the curriculum, and broadening and diversifying the management system that will accompany the program units.

At one point in the conference it was suggested that the idea of producing a science-oriented instructional system might be abandoned in favor of launching a massive effort to simultaneously improve all facets of the high school. It was the general feeling, however, that the difficulty of building and implementing a totally new high school program would be so great as to render such a project unmanageable. A more limited effort of the kind described above was favored because of its feasibility and because it would serve as both a compatible step in the right direction, and as prototype for broader future development.

A Word of Caution on the Task to be Done

The Callaway Gardens conferees made no attempt to spell out in detail what would be required to develop and implement a system of science instruction like the one that has been described. But a common concern along these lines was repeated many times.

It was emphasized again and again that building a flexible, multiyear, multidisciplinary, individualized high school science program is a job that should not be approached lightly. Among the accomplishments of the curriculum developers of the 1960's was their success in making clear how difficult it is to develop innovative instructional materials and to disseminate and make it convenient for schools to implement those materials. The people who manned the early projects found that this process requires considerable time and resources, and the attention of top flight people who devote full-time to the effort. Although the experience that has been gained could result in a number of efficiencies in any effort undertaken in the future, the extent of these should not be overemphasized.

School people, the educational establishment, and the funding agencies are urged by the conferees to recognize that building a quality program of the sort described above would be a much more difficult instructional development task than any that has been done to date. This kind of job would require an all out effort and will not be brought to a successful conclusion in a think-tank atmosphere or by a handful of teachers working together from 3:00 to 4:00 p.m. every Thursday afternoon for a year.

General Conclusion

It appears that the time has indeed come to design curriculum materials for the schools of the future. Many schools are already experimenting with individualized instruction, frequently with homemade materials that could stand improvement. The subject of science, encompassing elements of mathematics and social studies, would serve as an ideal focus for the development of an organized, well-tried instructional system. The conclusion of the Callaway Gardens Conference was that such a development should be instituted and encouraged on a nation-wide level.

APPENDIX I -- CONFERENCE PARTICIPANT LIST

APPENDIX II -- CONFERENCE WORKING PAPER

APPENDIX III -- CONTRIBUTED PAPER BY
ROBERT GAGNÉ
FLORIDA STATE UNIVERSITY
"THE HIGH SCHOOL SCIENCE PROGRAM --
A PSYCHOLOGIST'S ASSESSMENT"

APPENDIX IV -- CONTRIBUTED PAPER BY
CLIFFORD SWARTZ
SUNY AT STONY BROOK
"THE HIGH SCHOOL SCIENCE PROGRAM --
A SCIENTIST'S ASSESSMENT"

APPENDIX V -- REPORTS OF CONFERENCE DISCUSSION
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APPENDIX II

CONFERENCE WORKING PAPER

The time has come to design curriculum materials for the schools of the future. During the 1960's, new and excellent courses were prepared for the schools, particularly in the sciences. The large curriculum projects produced improved teaching tools of many kinds and also retrained a substantial fraction of high school teachers. The textbooks created by these projects have intellectual respectability.

In most cases, however, these new materials were designed for traditional instruction of students who would play traditional roles in school. Although there is some disagreement with respect to the exact nature of the difficulty, virtually everyone concerned with or affected by education feels that the traditional methods no longer adequately perform the functions that they should. Many high school students complain of irrelevant content, authoritarian teaching methods, and overly centralized decision making. Parents are alarmed over these things and over the high costs of the educational system as well. Teachers and administrators are uncomfortable because, although there is much rhetoric about the ills of education and there exist many general descriptions of what might be done to solve the problems, very little concrete help has been provided with which to get the remedial process underway.

Despite the recent efforts to improve the high school science curriculum, this area of the school program has received a share of the criticism. Some of the specific charges now being directed at the high school science program are as follows:

(1) Science teaching is generally group-centered and teacher-directed. Few provisions are made for the variations in interests, in ability, in learning rate, and in learning style, that we know exist among students.

(2) "Pure" science tends to be overemphasized at the expense of applied science. The content of high school science courses is inappropriate for most students who will not enroll in a college or university. Furthermore, the social implications of science and technology have not been considered.

(3) There is presently little correlation between the biology course taught at the 10th grade level, the chemistry course taught in the eleventh grade, and the twelfth grade physics course. Furthermore strong questions are raised as to the validity of the biology-chemistry-physics sequence and to the fact that the high school science program is limited to these three science content areas.

(4) The high school science instructional materials that have been developed by nationally based groups tend to be inflexible. The new materials, like the old, are designed for year-long courses. Students must commit themselves for a year, and the teacher and class together must commit themselves for a particular sequence of topics during that year. There are, of course, exceptions to these generalizations. There are ways in which a teacher can provide a very good route through the science topics. Some of the new curriculum products can be used by students for individualized study and progress. The total amount of such materials, however, is small and in general suitable only for students in the upper academic level. Furthermore, the materials consist only of isolated pieces that are clearly either physics or chemistry or biology or math. If an American high school today wanted to free its students from the course complex and arrange individualized study in all fields, they could choose from only a very small body of curriculum materials or administrative procedures.

(5) The new science curricula have failed to increase the percentage of students who take high school science courses. Most of today's high school graduates have not received an adequate general education in science.

It was mutual concern over the validity of some of the criticisms of the present high school science curriculum and the instructional materials that determine it which stimulated the several discussions leading to this paper. Those involved in the discussions concluded that the best way to make the needed corrections was to develop and disseminate a set of second generation instructional materials that would incorporate a fresh look at both the kind of science that high school students should study and the instructional procedures that should be used. Some of the features that the discussants felt should characterize such a new high school program are as follows:

(1) The science program should be designed so that it would provide interesting and useful work for all students for all the high school years.

(2) Minimum goals of scientific literacy and capability for high school graduates should be spelled out in operational terms. The curriculum materials should both prepare and test students at these minimum levels, but should also provide more advanced lessons and goals.

(3) The basic science program unit should be considerably shorter than the one year courses that now serve as that unit. A flexible three year program composed of roughly one hundred (one to three week program units) would appear to have many advantages. Such an arrangement would make science study flexible in terms of topics, sequence of topics, individual pace, and commitment.

(4) The total set of program units should deal with both basic and applied aspects of not only chemistry, physics, and biology, but of other sciences as well. Many individual units should cross traditional barriers of discipline so that they would not necessarily be identified as being chemistry, or physics, or biology, or science at all, for that matter. The topics should frequently have a theme of some real-world problem connected with human and social effects and with the applied sciences or engineering fields.

(5) The program units should be made as independent of each other as possible (complete independence does not appear to be desirable or feasible). It should be possible for students, teachers, school districts, and states to order the program units in different ways so as to accommodate differences in student ability, teacher preference, and local conditions.

(6) Each unit should provide a variety of ways of working towards particular goals. The variety should be provided by the preparation of different media, different reading levels, and even different conceptual approaches. For example, many scientific phenomena can be equally well approached through mathematical abstractions or through pictorial or physical models.

(7) The program units should be developed in such a way that students can do the activities at different rates dependent upon their abilities and interests. This means that the material must be designed for self study on an individualized basis, but with the guidance and occasional assistance of a teacher.

(8) The cost to the schools of the units that make up a proposed program should not exceed present expenditures for science instruction. For the most part, the program units should not call for large outlays of funds for new equipment or new facilities unless equivalent economies can be made elsewhere.

(9) Each unit of study should have its goal clearly spelled out so that the student will know exactly what he must be able to do to demonstrate proficiency in the topic. Such specifications are frequently called behavioral goals. It is possible to state these without resorting to the mystique sometimes attached to the use of the name.

We believe that the time is particularly propitious for attacking the problem of developing and introducing a more flexible and individualized science program. As a result of the use of ISCS science at the junior high level, the existing interest in, and the demand for, finding ways of breaking old patterns of standard classes and standard courses has accelerated. Many school systems are now asking what they should do at the high school level to maintain the impetus for individualized instruction that the ISCS program has begun in the junior high school. Furthermore, a large number of high schools are already experimentaing with science programs that are not too unlike the one upon which the conference will center. The comments from these schools and from other sources indicate that the demand for new programs of this kind is strong but that this demand will not be met adequately until new and appropriate types of instructional materials are developed.

The conference will be concerned mainly with the problem of creating individualized materials in the sciences. Any of the skills normally associated with other subjects - English composition, for example - can also be taught and tested using the same type of materials. Indeed, some students learn reading and writing skills more efficiently in studying science or music than they do in the formal

English classes. [illegible] clearly a body of human
knowledge that [illegible] considerations. The
materials that [illegible], would make it possible
for schools to [illegible] alized instructional system.
Creation of these [illegible] break the current dead-
lock in which [illegible] a system at least partially
if materials were [illegible] publishers have been reluctant
to become [illegible] yet a large enough market.

A Proposed S[illegible]

In order [illegible] discussions, we present
specific detail [illegible] al for preparing new
curricula material

As envisaged [illegible] proposed instructional
materials will be [illegible] and possibly audio-
cassettes. The [illegible] in sufficient quantity to
keep a student [illegible] years, and will be designed
to take the place [illegible] ology, chemistry, and physics.
The materials will be [illegible] students to do activities that
can be carried out [illegible] is that exist today in high school
classrooms -- that is, [illegible] very little new in the way
of equipment and [illegible] standard in most schools,
and they will require [illegible] specialized training for the
teacher. The topics [illegible] program of instruction will
be drawn from the full [illegible] science disciplines but will be
dealt with in such a way [illegible] be taught in a more or less
traditional mode or in [illegible]-disciplinary sequences chosen
by the teacher or school.

As has been indicated [illegible] innovative characteristic of
the materials is that [illegible] the scope and sequence of
instruction to be [illegible] student interest and local
conditions. To accomplish [illegible] materials will be constructed
in modular form. That is, [illegible] consist of short, fairly inde-
pendent units instead of [illegible] sequential textbooks. It will
be possible for a teacher [illegible] several of these units into a
more or less traditional [illegible] aim, however, is to make
individualized study poss[illegible] student moves through his
activities at a rate that [illegible] interest, abilities, and
vocational intentions.

Present plans call for roughly 125 units of instructional materials to be developed. Since each unit will be designed to keep students occupied for roughly one week, it is anticipated that a three year high school science program will consist of roughly 100 units. The purpose of providing 25% more units than any teacher will likely need is to provide teachers, schools, and school systems with options from which to choose units that will comprise their science offering. We presently anticipate that approximately one-fourth will be chemically oriented, that one-fourth will center on topics that can best be classified as physics, one-fourth will be biological, and that the remaining one-fourth will deal with topics drawn from the social sciences, psychology, and the earth sciences. Furthermore, the particular theme and focus of inquiry of any unit may be drawn from applied sciences such as medicine or engineering.

The units will be constructed to allow the student to proceed through them relatively independently. Each unit will spell out in fairly specific terms what the student should know, or be able to do, at the conclusion of the unit; will describe the tools that have been provided in the unit; will suggest ways in which the student might proceed to learn what is desired; and will provide self-tests through which the student can determine when he has successfully completed the unit. Each unit will be developed so as to free the teacher from most of his directorial and administrative responsibilities thereby enabling him to serve as a resource to individual students and/or groups of students who need help. Although the proposed materials will differ somewhat from the present ISCS junior high school materials, the role of the teacher in the new program will be very similar to the one now performed by an ISCS teacher.

As indicated earlier, the units will be made as independent of each other as possible, thereby allowing the sequence of topics dealt with in a one year course, or over the three years, to vary. We assume that the ultimate publishers of the materials will maintain their inventories in two different forms. Hopefully, a fairly large percentage of the finished units could be warehoused as separate entities to be assembled and bound according to the specifications of the consumer. For example, a selection of the units might be made by the California State Textbook Adoption Committee, and the publisher would bind the materials to these specifications and deliver tailor-made sets. The same would be true for those other states and school systems that purchase large enough quantities of materials to make custom binding feasible. To serve the needs of small school systems one or more "recommended packages" of units would be selected in advance, bound, and warehoused. These would presumably be marketed and sold in the same way as are present textbooks.

The general principles that are presently thought to apply to the units and to their development are as follows:

(1) Each unit will be as independent as possible and will be designed to encompass about one week of work by the average student. This means that a three year package will consist of roughly 100 units. Since roughly 125 units will be developed, teachers and/or school systems will be able to vary by selection both the scope and sequence of their three year science offering.

(2) Each unit will be composed of one or more modules. All students who do a unit do the activities contained in a "core module" that is written at the skill and conceptual level of the average tenth grader although the modules will be used by students in grades ten through twelve. Most units will also contain optional modules as well. Some of the optional modules will provide remedial help with some skill concept that is critical to the unit's core module. Other optional modules will extend the topic of the unit to a higher level than is possible in the core module. The optional modules will make the units appropriate for a variety of student ability levels. Less able or less interested students will do only the core module plus whatever remedial modules are needed. Brighter or more interested students will have the option of doing the more challenging activities contained in the modules designed to extend the topics included in the core module.

(3) In addition to the material contained in its component modules, every unit will provide the student with overview statements of the rationale and objectives of the total unit and a description of the competencies that the unit assumes. Each unit will also contain material that will help the teacher to understand how the component modules are related and what the unit is designed to do.

(4) Every module within a unit must be self contained and must include everything necessary for the student to learn the concepts intended and to acquire the desired skills. They must also include everything that the teacher needs to facilitate student learning and to assess student progress.

What components will be included in any unit or module within a unit will depend in part upon what the developers encounter as development is carried on. Listed below are the elements that it is now assumed will be included as part of every unit and/or module (we envisage the organization of the units and of the modules as being essentially similar).

(*1) Any necessary text materials will likely be in pamphlet form. The materials will be written so that they can be understood by an average student with as little input from the teacher as possible.

(*2) Instructions for carrying out any laboratory activities to be done will be part of every unit and module.

(3) Any loops, film, slides, and other audio visual items that are needed will be included. These materials must be in such form that the student can study them individually and without disturbing others in the class. For economy reasons we plan to limit the amount of audio-visual material included, with the possible exception of audio-cassettes.

(*4) There will be a description in non-mechanistic student language of what concepts the unit or module is designed to teach, or what skill the student should gain as a result of the module.

(*5) There will be highly specific self-test items through which the student can determine whether or not he has successfully accomplished the goals of the unit or module.

(6) There will be suggested answers to the self-test items written in student language. The suggested answers will include suggested mechanisms through which the student can correct any deficiencies he detects.

(7) Every unit or module will include any equipment or materials that cannot be assumed to be already in the classroom (we assume that needs of this sort will be kept to a minimum).

(*8) There will be a description of what the student is assumed to know and to be able to do in order to successfully begin the unit or module.

(*9) There will be a general description of what the unit or module is designed to do, with fairly flexible suggestions as to how the student might proceed through the materials to reach the goals that are specified.

(10) There will be materials to help the teacher to implement the module or unit.

Those items listed above that are preceded by an asterisk indicate things that probably should ultimately be supplied in individual student quantities. The remainder of the items could be supplied in classroom quantities. We are assuming that the individual student materials will often be stapled or stitched together prior to use by schools. This would be true of the teacher material as well. As projected, all other items would ultimately be supplied to schools as separate entities. If this turns out to be the case, each unit and module within a unit will ultimately consist of a combined set of printed student material, a combined set of printed teacher material, and assorted fragments such as pieces of laboratory apparatus, audio-cassettes, and so forth. A collection of these three kinds of material are what has been referred to earlier as a "unit" or a "module". When circumstances permit, the ultimate publisher could assemble a selection of units into a custom made package, composed of two books, or sets of books -- one set for the student and one set for the teacher -- and any other items necessary to do the work.

Content of the Curriculum

The content of most present day high school science curricula is limited to courses in biology, chemistry, and physics. Largely for historical reasons such subjects as geology, psychology, anthropology, archeology, meterology, economics and oceanography have been ignored. Furthermore, the applied sciences such as engineering have notably been excluded from the curriculum but have often been dealt with indirectly in such a way as to connote disdain.

In the proposed new materials we plan to present a more balanced view of science. In this approach we will deal with topics drawn from essentially all of the natural sciences and many of the social sciences. Furthermore, we will seek to deal with both the basic sciences and the applied sciences.

Because of the flexibility that we plan to build into the units that will comprise the three year course it should be possible to deal more effectively with the present lack of both breadth and overlap of content than have most programs. To accomplish this, we plan to follow a two-step process. First, those skills and concepts that appear to be fundamental to science without regard to discipline will be identified. Several units will be devoted to treating these topics. Each of these "fundamentals units" will deal with some basic topic and will show the application of this idea or skill in at least three specific science areas. One such unit, for example, might deal with the elements of probability and the examples dealt with might include gene combination, the behavior of gas molecules, and the flow of currency.

In addition to the fundamental units, other units will deal with more specialized topics that normally are parts of courses that deal with the specialized sciences. Examples of such units are the diversity of certain types of animals, the behavior of the halogen gases, electrical circuitry, imprinting, the geologic time table and ecological succession.

In assembling the units into courses it is assumed that teachers and school systems will use those units that deal with fundamental topics more than once. It is not intended that the teacher will teach the fundamental units first, followed by those that deal with the specific sciences. Rather, it is hoped that the fundamental units will be used at whatever points in the sequence that they are needed.

The identification of the topics for fundamental units will be a more difficult task than will be identifying those related more specifically to the specific sciences. Listed below are some examples of the kinds of topics around which the fundamental units will be built:

(1) A unit in which a student is taught to describe the operation of a typical negative feedback system. Included within the unit would be the concepts of systems, sub-systems, components, interactions, feedback, and negative feedback. Common examples would be taken from home heating systems, economics, biological systems, and mechanical speed control.

(2) A unit on energy designed to help the student to:
(a) Have firsthand experience with many kinds of energy.
(b) Describe in some detail energy conversions of many kinds.
(c) Tie the notion of "stickiness" to potential wells, particularly in the case of matter particles.

(3) A unit that deals with elements, compounds, and chemical change designed to accomplish the following:
(a) Give the student the model that there are a small number of elementary particles.
(b) Have the student learn the symbols for a dozen or so common elements.
(c) Have the student examine formulae for several compounds and learn what these formulae represent.
(d) Have the student examine several equations and learn what the equations represent.

(4) A unit designed to teach the student to measure such things as length, mass, volume, density, and temperature, using the usual instruments equipped with metric scales.

(5) A unit on simple mathematics aimed at teaching the student to handle functional relationships, particularly the linear, both algebraically and graphically. The tools required for this unit will be the use of decimals and the making of graphs.

(6) A unit dealing with experimental design including the setting up of control experiments.

(7) A unit dealing with the difference between observations and models and the interaction between them.

(8) A unit dealing with the nature of light and its interaction with a variety of systems.

The above list is, of course, only a partial one. As projected, about one third of the hundred units will deal with common fundamental topics. The remaining two thirds will deal with more specialized topics drawn from the special sciences, but usually studied in terms of applications of general concern to human life.

APPENDIX III

CONTRIBUTED PAPER BY
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"THE HIGH SCHOOL SCIENCE PROGRAM --
A PSYCHOLOGIST'S ASSESSMENT"

I begin by reminding you of a New Yorker cartoon which shows two engineers in hard hats standing beside a river. Arching over the river is a magnificent new bridge which is beginning to crack and fall to pieces in the middle. One engineer is saying to the other: "So much for the new math!"

Initially, I should like to describe some impressions that I have about high school science programs. Many of these programs were developed as a result of nationally organized curriculum-development efforts. I emphasize that these are impressions, and they surely are subject to correction. They are by no means based upon data which has been systematically collected, but rather upon general reading and upon conversations with various people who are concerned with these matters. Following this, I should like to try to draw some conclusions, and to explore what implications these impressions may have for future planning in this area. I shall try to say what they mean to me as a psychologist, as I have been asked to do. Perhaps I should mention that taking a psychological view primarily means to me interpreting the events from the standpoint of the human learner.

Accomplishments and Disappointments

All of us must certainly be aware of the substantial accomplishments of curriculum development during the last decade in the areas of science and mathematics. Various descriptions have been made of what the goals of these programs were, and what they seem to have accomplished. Perhaps the most important ones are as follows:

(1) The content of science materials has been modernized, and made to conform with current theories.

(2) New ideas reflecting new scientific developments and theories were introduced. An example is the whole DNA-RNA story.

(3) Correction was made of certain errors of interpretation, which may have been contributed by authors who were not themselves good enough scientists to detect them.

(4) Serious attempts were made to "purify" the content, in the sense of making it emphasize science and de-emphasize technology. This kind of change reflected a preference of designers for such topics as the study of the properties of electric force, in contrast to the study of how to connect wires to make parallel and series circuits.

(5) A greatly increased emphasis was introduced on the "process" of science, designed to reflect the activities of the scientist, as opposed to his conclusions.

(6) Science materials were designed to be intellectually more satisfying, and thus presumably more challenging to students.

All of these changes would appear to be improvements. However, after a period of five to ten years, it is evident that the new science materials have raised some doubts. Have these new courses managed to improve science education? Certainly it appears that there have been a number of disappointments:

(1) Although most curriculum development projects have gone through the motions of conducting evaluation studies, evidences of important changes in the fundamental intellectual repertory of students is hard to come by.

(2) In a number of instances there was considerable initial resistance to new programs on the part of parents. We heard a good deal about parental misgivings concerning new science and mathematics programs. To some extent this parental resistance has continued, and it probably should not be lightly dismissed.

(3) There also has been some degree of resistance on the part of teachers. Although most programs conducted teacher education efforts in the form of training institutes, summer workshops, etc., it does not appear that teacher resistance has been entirely dispelled.

(4) One of the prominent features of new programs is that they suffer from and continue to suffer from a kind of degradation of their purposes when they are implemented by teachers. There seems to be a tendency on the part of the teacher to regress to earlier methods of instruction when a new program in introduced; and this has been very difficult to overcome.

(5) Perhaps the most disappointing feature of all is that the prestige and appeal of science has not improved. Fewer students in high school now take science courses. Of coures, this tendency is undoubtedly influenced by changes in social values and attitudes which the programs themselves may have little opportunity of influencing. Nevertheless, this result has been an unfortunate concomitant of the introduction of these new programs.

(6) I understand it to be the case that the new course materials developed during the last decade have tended to be used for a year or two and then discarded. Of course, the even newer programs which replace them may to a considerable extent incorporate the same aims. However, this tendency may also be seen as one of returning to earlier forms of instruction, such as are exemplified by "standard textbooks."

Some Reflections on Curriculum Development

As one who participated to some degree in more than one of these curriculum-development efforts, but who at the same time attempted to maintain the viewpoint of an external observer, I ask the question, what went wrong? First, I don't think that is exactly the right question. As I look at these materials and the courses that were constructed from them, it would appear that they are very valuable, and that they are by no means inherently "wrong."

What kinds of things were overlooked that might have made the whole effort more successful? I want to describe five ideas about this question which I think should be borne in mind as we address the problem of what, if anything, should be done in the future.

Careful attention to goals. Despite frequent claims to the contrary, it is not clear that the goal of science as a part of general education, rather than of specialized education, has been taken seriously. If one wants scientific knowledge and scientific activity to become a part of every student's life, by no means all of the curriculum developments can be identified as having been in this direction. For a great many people, being able to distinguish parallel and series electrical circuits may indeed be a more important kind of scientific knowledge than demonstrating the laws of motion in the periodic movement of a pendulum. Modern math, I think, is almost too easy a target from this point of view. However much a student learns about the axiomatic structure of number systems, for many purposes of life, including the pursuit of science, he needs to know how to perform operations with numbers. There is some indication that this kind of life-oriented goal has been neglected, at least in the sense of being too greatly de-emphasized, in science as well as in mathematics.

What I am talking about is relevance. A relevant curriculum is one which meets the needs of all students, not just those of a dwindling few. Its goals are based upon the needs of all the people, not on the needs of college professors of science for "better prepared" students.

Clarity of objectives. You have all heard of the objectives of instruction, of "behavioral" objectives, and I do not intend to raise ghosts of some old and tired arguments. When I speak of objectives, I wish to talk about the outcomes of learning. I don't particularly care how they are stated, but I think people should try to construct clear communications about them, not fuzzy ones. One should be clear, at least, I think, about what one expects the student to be able to do after he has been instructed. I am not satisfied, nor do I think any clear-thinking person should be satisfied, with the idea that "exposure" to a "well-structured" set of topics will somehow, as if by magic, make the student into an admirably well-educated man, possessing all the virtues of the upright man of science.

[illegible] ularly true. I think, that one should be able to [illegible] number of different categories of objectives. If [illegible] attempting to convey a set of organized information [illegible] one should be frank about it, and admit this [illegible] to the student. And one should not pretend that [illegible] by itself teaches the student to solve ecological [illegible] calculate the amount of carbon dioxide in a sample of [illegible] become a superior thinker. In contrast, if one has in [illegible] outcome of changing attitudes toward air pol- [illegible] should be clear that such a class of objectives will [illegible] time make the student capable of knowing a great deal [illegible] the causes of pollution, or of being able to solve a pr[illegible] of pollution. Learning has different outcomes, [illegible] to keep them straight. Learning is a wonderful process, but it is not magic.

It is my observation that science courses and their topics are by no means always clear about their objectives. A lesson which apparently is aimed at establishing attitudes can easily end up teaching trivial information. A lesson apparently designed to convey [illegible] organized information can easily end up teaching an esoteric intellectual skill.

Capturing the interest of students. I shall not say too much about this, because it is mostly obvious. Of course, it is another component of what is meant by relevance. If instruction on the internal combustion engine is eliminated from courses in physics, perhaps for very good, idealistic reasons, what does this do to the appeal of the course, and to the number of students who elect it? At all levels of the education structure, we are reminded that we must tie into student interests, we must "meet students where they are," or else it is perfectly possible for them to drop out, either before or during the conduct of the course. I do not believe one should draw from this the generalization that student interest, at all age levels, should be the sole criterion of educational content. However, if we are attending to the high school at the moment, we should surely bear in mind that students of this age are not far from being adults, and perhaps we should go about equally far in treating them as adults, with regard to their interests in science. We may also have to become as concerned to see that they can formulate a correct English sentence as well as a bright ten-year old, as we are that they have learned any particular principle of science.

The system of delivery for instruction. Here is the rock on which most curriculum projects have foundered. Some of them, for example, have made assumptions about methods of delivering instruction that depend heavily upon the retraining of teachers, and upon their adoption of instructional techniquest that are new or at least non-traditional. Usually it has turned out that teachers have great difficulty learning and adopting these techniques. They do not acquire a commitment to them, and consequently the purposes of the newly devised materials are not fulfilled.

In other contrasting instances of curriculum development, assumptions are made about instructional delivery that are of a traditional nature, and these too run into difficulties when adoption of the new materials is being considered, because they fail to conform to new ways of organizing instruction. An example is provided by materials designed for teacher delivery and demonstration, when systems of individualized instruction are being used by schools. In such cases, materials which may be excellent in content can only be used after they have been treated by expensive adaptation operations.

My conclusion from this experience is that any enterprise of course or curriculum design ought to consider the "instructional delivery system" -- how are the students going to learn -- as a first order of business. It may be decided that a highly traditional method is preferred, or that a somewhat untraditional one, like independent study, is to be aimed for. But it does seem to me most important that these decisions be made first -- before one considers any details of content. Otherwise, this sin of omission will plague the enterprise, not only during its design period, but most importantly during the period of adoption and utilization.

The mode of instruction. Closely related to the question of procedures for delivery of instruction is the question of the mode of instruction, which means the arrangement of the actors in the instructional drama. Does the teacher occupy center stage, or background? Where is the student located? How many actors are there? What function is filled by the props, or "hardware"? Using traditional terms, this is a question pertaining to the use of lectures, laboratories, group discussions, televised lessons, and so on.

Much instruction in the school is still based upon the model which uses the textbook accompanied by either teacher lecturing or class recitation, or both. Viewed in terms of how learning occurs, it is difficult to provide a really good rationale for this combination. If what is to be learned can indeed be obtained by reading a text, a lecture over the same material or a student-by-student reinstatement of this material pretty obviously is a waste of time. This is the basic reason, I think, why thoughtful students see little point to high school classes, and become increasingly "turned off" by them. One must ultimately depend upon the student to learn what he is supposed to learn. Repeating it to him is unlikely to do much good. And if the purpose of recitation is to see whether he has indeed learned the material, why not do this more systematically, by allowing each individual student to demonstrate that he has learned when he is ready, rather than when the teacher happens to call upon him?

Science instruction has often been cast in the mode of the laboratory exercise. The difficulties of designing good laboratory exercises, and of avoiding the routine following-of-procedures, are well known. In contrast, good laboratory exercises take on the form of "projects," having definable goals, but whose outcomes cannot be predicted in terms of "coming up with a right answer." The advantages of this mode of instruction are several, and they are substantial ones. First, the student is confronted with a total problem-solving situation, which calls upon his knowledge, his skills, and his cognitive strategies. The situation is intrinsically motivating, particularly if the student has been permitted some choice of the exercise initially. And he must depend upon his own resources to analyze, organize, plan, conduct, and report the activity required to reach the goal.

Additional advantages to instruction are gained in such laboratory projects when they are undertaken by pairs of students, or by small project teams. Such an arrangement adds still another component of realism, since scientific work is often conducted this way. In fact, it might be argued that science is almost never an individual matter, in the sense of being private. It is always subject to public scrutiny and criticism, even when the public consists of a small set of highly knowledgeable colleagues. Still another advantage of conducting science projects in pairs or groups is the opportunity this provides for refinement and clarification of ideas occurring in the discussion and the give-and-take of a cooperative intellectual venture.

It seems to me that the mode of laboratory and field projects undertaken by small groups or pairs of students, or on occasion by a pair consisting of teacher and student, might well be seen as the most desirable instructional arrangement for most science instruction, even beginning in the early grades. I have mentioned its many positive advantages for effective learning. There is also a strong contrast here with the text-lecture or text-recitation kind of arrangement. In projects undertaken by pairs or groups, there is little evidence of time-wasting, so long as the activity remains devoted to the project goal. Of course, I recognize that projects themselves must be cleverly designed if they are to outdo in interest such activities as opposite-sex chasing, but that is generally true for most educational efforts.

Summary

Let me summarize in the following brief statements. Anyone who tries to take advantage of experience in curriculum development to undertake the design of new courses of instruction will profit by attention to the following actions in pursuing the goal of learning effectiveness.

(1) He will devote considerable attention to the defining of goals of the program to be designed.

(2) He will attempt to establish clear, communicable objectives, initially perhaps in the form of categories of objectives.

(3) He needs to be specifically concerned with the motivational value of what he designs, particularly in reference to its relevance to student interests.

(4) As a first step, he should make some decisions about the methods to be used to deliver the instruction, whatever its content.

(5) He needs to choose a mode of instruction which fulfills the purposes of his objectives, is appropriate to the subject itself, and which avoids wasting time. It should be a mode that engages students in activities that are as continually productive of learning as possible.

APPENDIX IV

CONTRIBUTED PAPER BY
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"THE HIGH SCHOOL SCIENCE PROGRAM--
A SCIENTIST'S ASSESSMENT"

Each of the preceding three speakers has explained that many of the things that he was going to say have been covered by an earlier speaker. I find myself in the same situation and, since this is the Bible Belt, during the lunch hour I looked at scripture for some advice. In the copy of the Bible which the Gideons have placed in my room I found words of both comfort and warning, in St. Paul's second letter to the Corinthians, the ninth chapter, the first verse, where he said, "For as touching upon the ministering to the saints it is superfluous for me to speak to you". It is noteworthy, however, that St. Paul then went on for five more chapters.

It has only been about a dozen years since scientists first became interested in the way science was being taught in school. I remember that at Brookhaven National Laboratory, a number of us became interested in the PSSC high school physics course which was just being developed. The popular view is that scientists became interested in these projects because the Russians had put up their earth satellite, Sputnik, earlier than the Americans. No doubt that national embarassment helped to provide funds for science curriculum revision, but it had very little to do with the motives of the scientists who actually took part in it. Like most of the scientists active in the projects, I became personally interested because I had young children and was appalled to discover the nature of science instruction in the schools. We should not forget that science instruction in those days, perhaps not so very long ago, was really bad. Let me characterize the situation by reminding you of the most popular high school physics text at that time, written by Dull, Metcalf and Williams. It's successor, incidentally, greatly improved after many revisions, is still the best seller. The edition that I remember in the late 1950's had a special feature that was widely advertised. It was a multi-layered transparency that illustrated the nature of physics. The advertising gave the impression that there were many such transparencies in the book. In fact, there was only one and that one showed a steam shovel down in an excavation. If you took away the top transparency you could look into the cab and see the driver with his hands on the control levers. When you took away the next transparency you could look into the gear box itself. That was a fair representation of the state of physics instruction during the 1950's. Some years after that edition came out, I was in the office of Dr. Hopkins who was the general high school science editor for Holt, Rinehart, and Winston. When I kidded him about the book and its transparency, he wheeled around in his chair, picked out the book and spread it on the desk in front of him. "Wasn't it frightful?" he said, "But it swept the nation!"

Let me describe the situation 12 years ago in another way. We ran an institute at Brookhaven Laboratory for all of the teachers who taught high school physics in Suffolk County. There were about 50 of them, of whom only six had studied physics in college for more than one year. Only one was able to use calculus at all, and it turned out that he was not a very successful teacher.

Under circumstances like these, what was needed was clear to us all. We should have a new text describing real, modern physics. There should be laboratory devices allowing first hand contact with important natural phenomena, and perhaps most important of all, there should be training of the teachers to fit them to use this new material. It should be training of the teachers to fit them to use this new material. It should also be pointed out that we never intended that this new high school physics course should be designed only for future scientists. We did, however, implicitly accept the fact that only the academic upper quartile of students would be taking the course. To this day most physicists would claim that PSSC is not a pre-professional course, but rather is an appropriate part of general liberal studies.

What has happened in the dozen years since that new facinating course was introduced? I would claim that many good things have happened, in many cases, directly traceable to the project and its spreading influence. Most of the high school physics texts are now respectable, having borrowed heavily from the liberating ideas of PSSC. All over the nation there have been interactions between teachers in the schools and scientists in the universities and laboratories. It is no small matter that it is now considered professional and respectable for a university physicist to be concerned with school science teaching. As a result of these interactions and of the many summer institutes, the academic level of high school science teachers has dramatically risen.

On the other hand, there has been no increase in enrollments in physics. Indeed, if anything, the percentage of students taking physics seems to be decreasing. At the present time, we seem to be engulfed by a rising tide of anti-science, that is to say, hostility toward science and technology and a fad for such irrational things as astrology. I would claim that the effect of the new math programs has been nothing short of a national tragedy. The programs as actually used in the schools have turned into a perversion of the goals of the originators. Max Beberman, one of the fathers of the new math, denounced its effects before his untimely death. Richard Feynman, the great mathematical physicist, was severely critical of the new math when he was asked to review possible textbooks for California schools. Let me illustrate his criticism by quoting just one comment:

"When we come to consider the words and definitions which children ought to learn, we should be careful not to teach "just" words. It is possible to give an illusion of knowledge by teaching the technical words which someone uses in a field (which sound unusual to ordinary ears) without at the same time teaching any ideas or facts using these words. Many of the math books that are suggested now are full of such nonsense-of carefully and precisely defined special words that are used by pure mathematicians in their most subtle and difficult analyses, and are used by nobody else.

"I would take, for example, the subject of sets. In almost all of the textbooks which discuss sets, the material about sets is never used -- nor is any explanation given as to why the concept is of any particular interest or utility. The only thing that is said is that 'the concept of sets is very familiar.' This is, in fact, true. The idea of sets is so familiar that I do not understand the need for the patient discussion of the subject over and over by several of the textbooks if they have no use for the sets at the end at all.

"A zookeeper, instructing his assistant to take the sick lizards out of the cage, could say, 'Take the set of animals which is the intersection of the set of lizards with the set of sick animals out of the cage.' This language is correct, precise, set theoretical language, but it says no more than, 'Take the sick lizards out of the cage.'"

What about the effect of these new science programs on college science courses? There have been some, of course, but not for the reasons we might have expected. Many of the more modern views of science have actually filtered upward to the college courses and textbooks. It is not the case, however, that we can now start off college science instruction at the sophmore level. There have been many attempts to find out the comparative performance of college freshman as a function of the nature of the high school science courses. These efforts have never been successful, probably because you cannot simply ask a student whether or not he had "PSSC Physics". I have seen some teachers who have been through summer institutes teaching a far more modern course using traditional materials than other teachers who had figured out a way to demand a rote memorization out of the PSSC Physics text.

It is an important matter that it is very hard to determine the effect of any particular change in education. We should all bear in mind the fable that is told by Stephens in his little book "The Process of Schooling." Once there was a primitive people whose king died. They dug a hole in the ground, tossed in the body, covered it over with earth, and as a parting gesture threw on some grain seeds. The following season they observed that on the grave there had grown a rich crop of grain. They were primitive but scientific people. Putting together cause and effect, they arranged the next year for another king to die and to be buried in the same way. Once again there was the hole, the burial, the disturbed earth and the seed. And once again there grew a crop of grain. Every year after that, they managed one way or another to find a king to bury. Over the generations there grew up a special class of experts who supervised the burials. Each year the ceremonies grew more and more elaborate -- different ceremonial clothing, different words, but always at the end the gesture of the thrown seed. Some years they had a good crop and some years it was sparse. Another group of experts grew up to find correlation between the details of the ceremony and the amount of grain that was produced. Although they did scientific experiments, year after year, which provided the theses for many doctorate degrees, they never could find any correlation between the ceremony and the product. And in all those years, they never thought to ask whether it was even necessary to put a king down there in the first place.

In spite of the warning of the fable, let me cite four reasons why we can hardly expect to see much change produced by the new high school science courses. First of all, science is still an isolated topic which barely touches the other academic courses. Indeed, high school science means only biology, chemistry, and physics. It is very rare to have any formal study of medicine, engineering or any of the other applied sciences. Secondly, the great majority of schools still offer the traditional trio of science courses in a perverted sequence. Biology is given first, sometimes to ninth graders, in spite of the fact that the new biology courses cannot really be understood without knowing a considerable amount of chemistry. The study of that subject comes the following year heavy with such topics as atomic energy levels which will not be formally introduced until the end of the following year in the physics class. Fewer than 20% of our students take all three of these courses. The third problem is that although almost all students have to study science in junior high school, it has only been within the last few years that there have been good revised courses made available for that age group. It will be some years before we have a sizable group of students who have been exposed to the new science courses all the way from elementary school to high school. Even then the chances are that we will not be able to see any effect at the college level. The fourth point concerns one of the main factors in trying to do education experiments. The delivery system for the new curriculum projects is dominated by the schools themselves and the nature of the teachers. In our standard schools the filter effect is unavoidable. What actually happens in the classroom has been filtered through the teachers experience and personality, and may bear very little relationship to the intentions of the group that laboriously worked out the curriculum details. I remember once standing in the back of the classroom watching a skilled teacher who had attended one of our summer institutes. He was explaining to the class why they would have to abandon the Bohr model, since they had learned about the wave nature of the electron. He pointed out with a blackboard diagram that the uncertainty of position of the electrons was so great that they could not be pinned down into circular or elliptical orbits. He then drew a picture of something that looked like a closed sign wave orbit and after considerable hand waving persuaded the class that we now know that electrons follow that sort of path around the nucleus.

Can anything different and better be done in science instruction? We had a school science materials show at our university the other day. I was very impressed by the high quality of many of the textbooks at every level. The apparatus and the teaching aids were plentiful and clever. In physics instruction we are almost embarrassed by the amount of material made available, particularly now that there is Project Physics. But still most of this material is designed for use in our standard classrooms during the taking of standard courses. We certainly do not need more material of this type. That would only have the effect of burying the king in different clothes. The problem is more complex and what we have not tried on a large scale is a drastically different system of schooling.

The particular type of instruction that we have come here to consider is certainly not new, but its potency for radical change is not generally recognized. We are going to consider ways to individualize instruction. Before I make claims about the ways that individualization can change the nature of our schools, let me define what I mean by individualization in instruction. People have various impressions about those words, some of them quite emotional. At one extreme, there is a mental image of a student in a closet, wearing a headset, staring at a video tube and with his hands on a computer terminal. At the other extreme, there is the nightmare of students left completely on their own or perhaps voting to decide what they want to do in their independent studies. The system that we are talking about has nothing to do with either of these extremes. It is a highly structured system of goals and sub-goals defined by proficiency exams. For each of these sub-goals there are curriculum materials available that tell the student what is required of him and how to go about preparing to demonstrate his proficiency. In a complete system there would exist an elaborate matrix of such assignments through which each student would wend his way, at his own pace, though prodded by an adult counselor, and leading toward goals that would be determined by the student and his parents within the guidelines of the system and with the advice of his counselor.

Let me point out briefly the changes that such a system would make in some of the problems that we have already noted in our standard science instruction: (1) The standard course topics could change. Instead of having a year long course in biology and then in chemistry and then in physics, modules could be developed around themes that would be of immediate practical interest to the student. These themes, for instance, could bring up problems normally considered only in social studies and could involve studies in medicine, ecology, math, engineering and statistics. (2) There need no longer be a problem of which comes first, biology or physics. Courses, as such, would not exist. The tight sequence that we have had in the past, seldom understood by the students, is not needed. Most topics can be approached in a fragmented way when they are needed for the solution of some problem. To learn how a rainbow is produced, for example, it is not necessary to commit oneself to a year-long course of study that starts out with vectors -- which is our present practice. (3) Teaching materials produced in short modules and designed as much as possible for self-learning, are available for public scrutiny and criticism. We get away from the closed classroom door and from the filter effect produced when all information must come through the teacher and his lecture presentation. Furthermore, with curriculum material in this form, it is possible and easy to change it rapidly, either for different emphasis or to bring it up to date. (4) With such material the role of the teacher drastically changes. The teacher becomes an aid to learning and not the prime source of information as well as authority. This is a far more normal role for most teachers who would be relieved of the fallacious responsibility of trying to be expert in all brances of their subject. Incidentally, the experience of most trials of this sort of material has been that most teachers can assume this new role more easily. Very little special training seems to be necessary. (5) Individualized instruction provides a new role for the student and creates a completely different atmosphere within the school. Although the student must assume more responsibility for his work, he is granted considerable freedom in organizing his moment-to-moment activities. In particular, he is not locked into a classroom chair for a specific period of time, nor does he have to abandon an interesting project because a bell rings. During the years of this century, individualized instruction has been tried with every age of student and with every socio-economic group. Even though the materials for the trials have been crude, the system seems to have worked in all of these circumstances. (6) The nature of the physical plant can be different in a school using individualized instruction. Although the system can be introduced and has been demonstrated in standard schools, it works most naturally without the confinement of standard classrooms and corridors. In particular, it allows a great variety of activities that cannot easily be done in classrooms, such as projects outside the school itself.

If this system of modular materials and individualized progress is so successful and can create such great changes, why haven't more schools adopted it? What happened to those many trials during the last few decades? The reasons are complex but the simplest explanation is probably the most important. There have never been sufficient good materials for schools to adopt the entire system. Let me cite two recent experiences. This past winter a movement was started among students, teachers and some parents, to institute individualized instruction in our local village high school. The obstacle on which the venture founded was the lack of suitable curriculum materials. As a matter of fact, physics instruction at the local high school is now provided on an individualized basis. But this is because three very hard working teachers created sufficient materials modeled after the course that I had developed at the college level. At a conference at MIT a few weeks ago, almost five hundred people showed up to learn more about individualized instruction in college courses, primarily in the sciences. In spite of the interest in the trials, very few people had enough materials available so that someone else could adopt a complete system in his own college. As most of us here know, it is extremely complicated and time consuming to produce a large amount of good curricular material at any level.

It seems to me that the time has come for the development of individualized curriculum material in high school science, if not in all subjects. There is considerable dissatisfaction with our present courses. In many schools throughout the nation they are experimenting in various forms of independent study for individualized work. In the 1930's, there was similar enthusiasm for these methods but the sufficiently large body of curriculum material was never developed. Schools cannot develop this material themselves anymore than individual schools could have produced a PSSC or a CHEM study of ISCS projects. It is an enormous undertaking and requires a nation-wide effort. The time has come and we are at least the nucleus of a group that could bring it about.

APPENDIX V

REPORTS OF CONFERENCE

DISCUSSION GROUPS A, B, AND C

Summary of October 29 Meeting of Discussion Group A

Arnold Strassenberg, Chairman   Richard Merrill, Recorder

The following is an attempt to summarize and organize the major ideas that came forth in an exciting day of spontaneous discussion. No attempt has been made to detail the chronology of the discussion or, in most cases, to associate ideas with the individuals who advanced them. The report does seek to indicate areas of substantial agreement and disagreement within the group.

The ideas fall into four general categories: (1) Should something be done? (2) What is the intended clientele? (3) What should be the goals, objectives and content, or how should they be arrived at? (4) What should be the nature of the "delivery system"?

(1) Should something be done?

There was general agreement that the status quo leaves something to be desired and that further substantial work on the high school science program is needed.

(2) What is the intended clientele?

There was considerable discussion on this point. Views expressed included the following:

(a) We can't forget those students who will become scientists. Don't sell science short or water it down in the name of "interdisciplinary" studies. "Science can be fun" is not an adequate guide to program development. We can't sacrifice rigor for those who need it.

(b) It may be unrealistic to think that we will ever reach all students. Maybe some "dropouts" are beyond help. This point was debated vigorously. Most participants felt that no category of pupils should be "written off" at the outset in the planning of the new program being discussed here.

(c) We may be aiming primarily at the 60% or so of high school students who now take no science beyond that which is required in high school.

(d) Science instruction for some students may mainly be a means of turning them on to learning rather than an end in itself.

(e) No one program, however flexible, will be a panacea, or even be appropriate for all students. School is for everybody.

For some (college-bound, and particularly college-science-bound), it may be enough to update, repackage, individualize, and render more flexible the college-prep courses now available.

For the "middle 60%", we may need to develop a "citizen science" for informed participation in society. It should have a heavy social science flavor and should be issue-oriented and packaged for individualization.

For the "lower 20%", we may need a "consumer science" geared to decision making for personal survival. Social science content should be incorporated.

(f) We might do well to leave the "repackaging" of present college-prep science curricula to others and concentrate on the crucial need for science for those who are not now well served.

There seemed to be general agreement on this last point, although it was also pointed out that some of the "science for citizens" could well become a part of the curriculum for college-science-bound students, even though they are reasonably well served by the present science courses.

(3) What should be the goals, objectives, and content, and how should they be arrived at?

It was acknowledged that a multidisciplinary, individualized science program with some attention to social implications, such as the one described in the working papers, would be a step ahead. For the intended clientele, however, several participants expressed the feeling that a much broader program, involving real integration of natural and social sciences, is needed. Questions were raised as to whether this would be too much to attempt as a next step, and whether it was realistic to expect that funding might be obtained for such a radical departure. The opinion was expressed by several that schools not only are ready for such an innovation, but that they desperately need it. It was also felt that perhaps a project of this magnitude and daring would be more likely to receive funding under present conditions than one which concerned itself primarily with reorganizing and repackaging sciences. The difficulty in developing such a program and "selling" it both to funding agencies and to schools was not dismissed lightly, however.

It was noted that if the scope of the program were to be broadened to encompass the social sciences on an "equal partnership" basis, the development of goals, objectives, and learning experience would require participation by specialists in the sciences, social sciences and education, and perhaps students as well. While recognizing its own limitations in proceeding too much further to define the scope and goals of the program, the group did discuss a number of ideas and possible "frameworks" for further development. Some comments about the "delivery system" are inextricable from these considerations.

(a) We should be concerned not only with content and processes of science but with student's resultant attitudes toward learning. Too much concern for immediately measurable behavioral objectives could cause us to ignore things that might enable and encourage the student to continue learning on his own in the future.

(b) Even in a multidisciplinary program, some goals will relate specifically to the student's knowledge and appreciation of the disciplines involved, of science as a way of thinking, an intellectual pursuit and as a human enterprise, and to the distinctions between science and applied science or technology.

(c) We should not assume that for students who are less academically able, it is sufficient or even desirable to simply emasculate science content, or present it at a slower pace.

(d) The goals should include: Scientifically literate citizenship. Awareness of the physical world. Science as a way of thinking.

(e) One framework for goals might be the following:

(A) Goals for the citizens:

(1) Survival (personal and societal). Knowledge essential for the voter. For instance: (1) we can't violate the laws of nature, (2) many scientific and technological problems can be solved, given time and money, (3) every action affects something else, (4) the magnitude of variables is crucial, (5) the entire system should be considered, (6) scientific methods can be used for many problems, (7) applied sciences will permit/cause drastic changes in our way of life, (8) we need practice in using, understanding and making value judgments on the basis of readings from instruments, (9) the public needs to know how to evaluate proposals made by scientists, (10) the public needs to know what the important technological issues of the day are and be able to evaluate consequences of various courses of action.

(2) "The beauty of science." Knowledge for the curious, such as (1) processes that related to everyday lives, (2) the science and technology behind what we see, (3) the relationships of science, technology and history, (4) basic information about natural phenomena, e.g. atomic theory, kinetic theory, stellar and planetary systems, etc.

(B) Philosophy of science (processes and methods, relationship of models to evidence, etc.)

(C) Basic principles and vocabulary of science, e.g.

(1) Forces cause motion.

(2) Motion occurs at finite rates.

(3) Many natural phenomena are related by mathematical relationships.

(4) Laws of nature limit what is possible and define what is difficult.

(f) Science Framework for California Public Schools identifies goal areas as follows

(A) Develop those values, aspirations and attitudes that underlie the personal involvement of the individual and his environment with mankind (e.g. interest in natural phenomena, response to beauty, recognition of limitations of science, objectivity, suspended judgment, etc.)

(B) Develop the rational thinking processes which underlie scientific modes of inquiry (e.g. classifies, hypothesizes, generates relevant data, infers, tests predictions, identifies variables, etc.)

(C) Develop fundamental skills in manipulating material and equipment and in gathering, organizing and communicating scientific information (e.g. observation, recording of data, graphing, handling apparatus, etc.)

(D) Develop knowledge of specifics, processes, concepts, generalizations, unifying principles, etc. (Appendix A to Framework discusses major conceptual systems of science.)

(g) Other ways of organizing objectives have been developed by NSTA, National Assessment, etc., and are worth considering.

(4) What should be the nature of the delivery system?

Again, here are some of the ideas expressed, and some of the possible bases of organization suggested.

(a) Modules smaller than normal courses are desirable for flexibility. Uniform length is not necessary or desirable.

(b) It is unrealistic to expect that all or even many of the modules can be totally independent of one another. In some cases, sequencing will be needed. Nevertheless, many possible sequences and combinations of modules should be possible.

(c) Some "core modules" or "fundamental modules" may be necessary.

(d) Modules should be capable of modification, extension and adaptation by teachers and students.

(e) Modules need to take into account different backgrounds and motivations of students, not just I.Q.

(f) Students should have real, but not unlimited, options with regard to the objectives they seek, the modules they utilize, the sequence, the rate of progress, etc. Options should include that of attempting something at which they may fail (and learn thereby) although the normal experience should be success. Options will be chosen in consultation with the teacher.

(g) Evaluation of student progress should involve a considerable element of self-evaluation, especially with respect to affective outcomes.

(h) Different sets of modules should allow different students to achieve some of the same objectives in different ways.

(i) Some modules could be problem-oriented, others primarily discipline-knowledge or skill-oriented.

(j) Some modules could be mainly support units for others. (Nodular modules.)

(k) The nature of the modules should cast the student in the role of an active learner.

(l) The role of the teacher in the proposed program is so markedly different from his conventional role, that a system to enable the teacher to assume this new role must be a major aspect of the curriculum development effort.

(m) The organizations of the program should probably be based on problems of significance to society and of interest to students, rather than on disciplines or discrete topics or processes. The structure of the course should make it necessary for the student to obtain knowledge from the disciplines to use in solving or better understanding the problem that is his current base of study.

(n) Some major areas within which appropriate interdisciplinary problems might be formulated include: environmental problems (population, resources, energy sources, pollution); communications; direction of change; health; decision-making; survival; quality of life.

(o) Some major content themes were identified. These might form the basis for some modules, or might be guides to selection of problems.

Possible themes that are related to both natural and physical sciences include

(A) Ways of knowing - how we get engaged with the world.

(B) Specialization and human knowledge; functions and limitations.

(C) Measurement

(D) Orders of magnitude

(E) Approximations - usefulness

(F) Uncertainty and Probability

(G) Decision-making with incomplete information

(H) Controlled and uncontrolled experiments - directed observations

(I) Hypothesizing and hypothetical testing

(J) Models and reality

(K) Systems - feedback

(L) Mathematical - analytical - logical thinking

(M) Values, evaluation, and science

Two other sets of possible content themes were:

Set I	Set 2
Energy	Nurture
Cybernetics and Systems Theory	Maintenance
Probability	Continuity
Change	

(p) The group explored several variations of a matrix that might serve as a guide to the development of an overall structure, or might serve to express the structure once it is formulated. A matrix of this sort could also be helpful to students in identifying learning modules that would help them meet their chosen objectives.

Goals and Objectives

(e.g. from California Framework or other sources)

Learning Experiences	Attitudes	Rational Thinking Processes	Skills	Knowledge
I) Problem Area (e.g. communi- / cation)	X	XX		
A) Specific Problems			X	
B)				
C)	X		X	
1) Modules	X	X	X	
2)				
3)				
a) Sub modules	X	X	XX	X
b)				
c)				

The "content themes" described might be used as criteria to select the rational thinking processes, skills and knowledge that should be included.

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P. Fordyce
R. Merrill, Recorder
I. Morrisett
S. Olsen
J. Withers

Summary of October 29 Meeting of Discussion Group B

E. J. Piel, Chairman J. A. Young, Recorder

The first question discussed by the group was whether or not the present deficiencies in the high school science program are sufficiently important to warrant a major effort to redesign the program. There was general agreement that the content of the high school program and the pedagogical approach commonly used to teach science are drastically inadequate for the reasons indicated in the conference working paper and others, and than an effort to design an alternative to present practice is not only warranted but almost essential.

Possible General Characteristics of a Modern High School Science Program

After agreeing upon the serious weaknesses of current high school science teaching, the group tried to agree upon some general characteristics that should apply to any new science instructional program that might be developed. Two principle statements, one related to content and the second related to pedagogy, emerged. These points are summarized below:

(1) The group proposes that the principal content thrust of the science program for most students should focus upon giving the student the tools and understandings he needs to solve the kinds of "real world" problems that he presently encounters and, more importantly, the problems that he is likely to encounter in the future. Some specific guidelines for selecting content that is in line with this general objective are:

(a) Any topics chosen should be of real interest to the student at the time he studies them. "It's good for you" or "it's good science" are not sufficient reasons for introducing a topic into the program.

(b) Any topic to be included in the program should have definite future utility for the student. A reasonable question to ask while selecting topics would be: "How could and/or will the student use this information or skill five to seven years after he finishes the program?"

(c) In selecting topics, emphasis should be placed upon utility as opposed to their contribution to "pure" science. Although "pure" science certainly has a place in the high school science curriculum, for most students it should probably serve as a means by which to understand broad questions rather than as an end in itself.

(d) The potential of a topic for helping a student to understand one of the science disciplines or even to understand the overall discipline called science is not sufficient grounds for including it in a new program. Although some discipline-centered topics that have utility potential should certainly have a place in a modern high school science curriculum, most students should probably spend considerable time in studying topics of a cross-disciplinary, multidisciplinary, or interdisciplinary sort.

(2) With respect to the pedagogical style of a new science program, the group agreed that it should foster a more personalized form of education than is currently the case. At a minimum, it should enable students with different interests and abilities to travel at differential rates through variable sets of learning activities that are aimed at producing outcomes that will vary with the individual. Put into operational term, this meant to the group that instructional materials should take the form of: a self-assigned (chosen) set of modules (units) with multiple entry paths, geared to various levels of sophistication and/or depth of treatment, with varied objectives that lead to multiple exits, that is not directed exclusively toward any specific group of students such as the disadvantaged or the college-bound.

Possible Specifics for a New High School Science Program

(1) During the second portion of the discussion period, the group tried to identify some of the kinds of specific topics toward which units or modules might be directed. A considerable portion of that discussion centered upon the question of what general concepts underlie all disciplines. This quickly led to a discussion of systems analysis which seemed to the group to be a fruitful area from which to draw topics for interdisciplinary units. During that discussion, the following possible topics for units were identified:

(a) The nature of hierarchy.

(b) The interdependence and interaction of subsystems.

(c) Material, energetic and informational linkages and linkages denoted by values.

(d) How do we know what we know (epistemology: equilibrium and feedback (negative, positive))?

(e) Analysis and synthesis as inquiry tools.

(f) The process of decay.

(g) Conservation: of matter, of beer cans.

(h) Transformation of matter, of beer cans (productive, destructive).

(i) Differentiation and coordination (of parts).

(j) The evaluation of a complexity.

(k) The importance of accident.

(l) The utility of the imagination.

(2) The group felt that concepts such as the ones listed above would allow a student to tie many topics together without first needing to know a great deal about any of the topics, and additionally would help the student to discover his own place and his function in the system of which he is a part. These considerations then suggested further topics which may have future potential utility for the student:

(a) Human health (toward self-diagnosis, the self-recognition of observations):

(A) Blood pressure

(B) Nutrients

(C) White blood cell count

(D) How muscles move

(E) Nerve impairment

(F) Poisons

(G) Joints

(H) How do I tell if I'm pregnant?

(I) What's good nutrition?

Some other topics that the group felt may be of use but that are not as generalizable were:

(b) Why don't we control the weather?

(c) Sex and alcohol.

(d) Structure of the protein molecule.

(e) Life without air.

(f) The sex life of a virus.

(g) Dinosaurs

(3) Finally, the group sought to identify some broad themes that might be kept in mind as units were developed. Whether the themes should simply be allowed to arise naturally from units or if clusters of units should be directed at developing one or more of the general themes was debated but not resolved. The themes identified were:

(a) Esthetic enjoyment, the quality of life.

(b) Economic and societal implications of the use of natural resources.

(c) Decision-making in a technological society.

(d) The vitality of models.

(e) The limitations of science and technology.

(f) The storage of information.

(g) Living with TV commercials.

(h) My likes and dislikes.

(i) The nature and characteristics of systems (an explicit treatment which would sublime some of the topics mentioned earlier).

The group tended to reject an explicit discipline-oriented basis for development of units such as seemed to be suggested on page nine of the conference working paper. We feel instead that the "disciplines" should pervade many of the units but that few units should be devoted to single-discipline concerned topics.

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Summary of October 29 Meeting of Discussion Group C

L. V. Rasmussen, Chairman   Morris Lerner, Recorder

The committee first focused on the need for new science materials by assessing the validity of the charges directed at the present high school science program in the five statements made on pages 1 and 2 of the working paper. The statements included in the paper were accepted as valid with certain amplification of terms.

The term "applied science" as used in statement number 2 was taken to mean technology in the modern sense (rather than trivial applications in "how to do it" format). Some concern was also expressed that the term "general education" not carry too broad or too diffuse an interpretation. The wording could perhaps be modified or changed to better indicate those elements of the scientific enterprise which should be part of the cultural arsenal of all informed and participating citizens.

In addition to the limitations of the present high school science program that were spelled out in the working paper, the group felt that certain other pertinent problems should be pointed out. These are:

(1) The present lack of public appreciation of science as a cultural activity suggests that the present science programs are failing to meet a critical objective.

(2) The present programs do not take into account the existing skills of entering students.

(3) In existing programs, there is little differentiation of goals for specific groups of students.

(4) Few present science programs deal effectively with the problem of defining instructional goals and determining the effectiveness of instruction; i. e., there is no way of meeting the requests and in some cases demands of interested parties for an accounting as to the effectiveness of science education.

(5) Present programs are designed for existing schools and administrative procedures and are not particularly appropriate for new schemes such as team teaching and modular scheduling.

The group felt that it was important to emphasize the difference between individualized study and "individualized instruction" as outlined in the working paper. Current science materials can be studied by individual students in isolation, but are not appropriate for individualized instruction which involves adjusting the instructional rate and sequence to suit the needs of individual students.

Form of the Program

Once the group had reached agreement upon the critical need for an alternative to the present high school science program, we focused upon the question of what form such a program should take. After considerable discussion of the modular plan presented in the conference working paper, the group agreed that the basic plan was a sound one. Several points of interpretation, clarification, and addition were raised, however. These are summarized below:

(1) As indicated in the working paper, the basic planning element of the system should be the unit of which roughly 100 would constitute a three year package of instruction. But every unit should be designed to accomplish learning outcomes in the three categories of

(a) Information

(b) Intellectual skills

(c) Attitudes

The weighting of these three categories of outcome would vary from unit to unit as desirable. In addition, collections or sequences of units might be designed to enhance the students' thinking and problem-solving strategies.

(2) Certain additional considerations should enter into the form of the units as follows:

(a) Problems (topics) for units should often center upon applied science in a social setting.

(b) An instructional management system(s) must be developed if the instructional units are to be used efficiently and well.

(c) The teacher must be given the tools with which to assess student progress in each unit.

(d) All units should be available for choice at any grade level and possibly for pre-high school and adult use as well.

(e) The program should include recommendations as to minimum levels of student competencies to be achieved and as to those units which have been designed to produce those basic competencies.

(f) As suggested by the conference working paper, there should be specificity of objectives; but it should be understood from the outset that there will likely be important instructional outcomes from the new program that will not be immediately measurable.

(g) Any units that are developed centrally should be considered as a core from which local schools and school systems could depart. Schools and school systems should be encouraged to develop additional units of a local character and to the degree possible the new program should include provisions to assist schools in producing high quality additions to the initial package.

Suggested Developmental Procedures

The last question discussed by the group was "How might an individualized, multiyear, multidisciplinary high school science program of the sort being discussed be developed?" Within this broad question, the first topic to be dealt with was possible mechanisms for defining the content of the proposed modules both collectively and individually. Two broad generalizations in this regard were agreed upon. These are as follows:

(1) It is critical to obtain broad input in the process of deciding upon content. Among the interests that must be represented are the following:

(a) Science teachers

(b) School administrators

(c) Scientists, particularly those with cross disciplinary interests

(d) High school students

(e) Parents of high school students

(2) Determination of content cannot and should not be made without considering what would be required for subsequent development and dissemination. Although educational innovation is the desired goal, this goal will not be served unless the problems (topics) identified as the focus for units can be converted by developers into student activities that are appropriate for an individualized program that is acceptable to school people.

Several suggestions were made as to possible ways to identify the topics and/or problems for the units to be developed. Although no consensus was reached as to procedures, the comments of group members are listed below in the order they were made:

(1) One large committee with broad representation might be assembled several times to work up a tentative list of topics that could later be modified if necessary by development teams.

(2) A series of fairly loose studies in the form of opinion polls, interviews and questionnaires might be made to assess the opinions of students, teachers, scientists, etc., as to possible content for the units. The results of these surveys could then be considered by a small group as they identify the specific topics to be recommended to the developers.

(3) A series of local conferences with broad representation might be held. Each conference report could then be considered by a small central group as they identify the specific topics to be recommended to the developers.

(4) Selected individuals might be asked by mail for their suggestions as to topics and/or outlines for topics. This input would then be considered by a smaller group who would determine the list of topics to be recommended to the developers. Those individuals whose suggestions prove to be acceptable might then be asked to do, or participate in, the actual development of units.

Near the end of the discussion period, the group focused for a short time on the mechanics of producing a program once the content for the units had been specified. Listed below in random order are the suggestions made during that discussion:

(1) The proposed modular approach to instruction would permit some decentralization of development. However. because of the need for technical assistance, the difficulty of communications, probable funding limitations, the need for coordinated field testing, and other matters, it would probably be necessary to restrict the number of places where development occurs to a fairly small one.

(2) The problem of how much technology to introduce into the program will require considerable study. While on the one hand an impressive case can be made for the instructional advantages of including TV and audio tapes, films, computer terminal presentations, etc., on the other hand these things are difficult to develop and expensive to produce and use. Unless some evidence can be found that schools are able or will be able to implement a technologically oriented program, some constraints will likely have to be accepted in this regard.

(3) In evaluating the program, it would seem to be wise to use a three step approach as follows:

(a) As units are produced, they would be field tested individually on the basis of the goals for that unit. When revisions on a particular unit are complete, that unit would be released to a distributor for schools to use as they see fit.

(b) When a reasonably large number of units are available, an instructional management scheme would be developed that suggests how the units might be used collectively most efficiently. Among other things, this scheme should include one or more "road maps" that suggest for a school's consideration various sequences in which the units might be used; a mechanism by which the teacher can monitor student progress and make rational instructional decisions for individual students; and a process whereby any equipment involved can be kept under reasonable control. When the management scheme is complete, it and the units which it encompasses should be field tested as a total system. After any necessary revisions in the management scheme, the total system would be made available to schools through a distributor.

(c) Once the total system is in the field, a summative evaluation effort should be carried out. This might be done by a group or groups other than the development group.

(4) Some provision should be made for assisting local school systems to develop additional units which take advantage of local conditions, interests, personnel, or resources, and which are consistent with the centrally developed units and instructional management scheme. This would probably involve developing a training program for local use on "how to develop units."

(5) It might be advantageous to identify early in the process of development the ultimate distributor of the materials rather than to wait for this until the materials are well along. Some of the possible advantages of this move are:

(a) Communication between developers and the distributor would be enhanced.

(b) The technical expertise available to the distributor (i.e. editors, artists, film producers, marketing surveys, etc.) could be utilized in the developmental process.

(c) As a condition for participation, the distributor might be asked to contribute to the necessary funding.

(d) The distributor could be built into the developmental plan as the element of continuity after the project was concluded.

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