DOCUMENT RESUME

ED 042 657 24 SE 010 038

AUTHOR Deall, Louis
TITLE Development and Implementation of a New Type Program of Secondary School Physics, A Four-Year, Independent, Individualized, Modular Program, Final Report.
INSTITUTION Clayton Public School System, Mo.
SPONS AGENCY Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO BR-8-F-022
PUB DATE Dec 69
GRANT OEG-6-8-008-022-0009(057)
NOTE 33p.

EDRS PRICE EDRS Price MF-$0.25 HC-$1.75
DESCRIPTORS *Curriculum Development, Independent Study, *Individualized Instruction, Multimedia Instruction, *Physics, *Program Descriptions, Program Evaluation, *Secondary School Science, Student Testing, Teaching Methods

ABSTRACT

Reported is a project designed to develop and implement a secondary school physics program that allowed for student variation in individual learning style, mathematical aptitude and topical interests. Initiated in 1967, this four-year individualized, modular program is divided into four major phases: (1) introductory and instruments, (2) mechanics, thermodynamics, fluids, (3) wave motion, electromagnetism, electronics, and (4) modern physics. Each phase is subdivided into topics, which are highly structured in the beginning but yield gradually into independent study units. This report describes the project objectives, the Physics Center where the program was conducted, the methods used, the evaluation procedures, and the outcomes of the program. There is a comparison with the traditional approach. A number of specific recommendations concerning the program was made. The appendices identify the basic phases, the levels in each phase, and the topics in phase I. (LC)

BR 8-1
PA

SE

ED0 42657

FINAL REPORT

Project No. 8-F-022

Grant No. OEG-6-8-008-022-0009 (057)

DEVELOPMENT AND IMPLEMENTATION OF A NEW TYPE PROGRAM OF SECONDARY SCHOOL PHYSICS

A FOUR-YEAR, INDEPENDENT, INDIVIDUALIZED, MODULAR PROGRAM

Lewis Deall
Clayton Public Schools
7530 Maryland Avenue
Clayton, Missouri 63105

December 1969

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

SE 010 038

FINAL REPORT

Project No. 8-F-022

Grant No. OEG-6-8-008-022-0009 (057)

DEVELOPMENT AND IMPLEMENTATION OF A NEW TYPE PROGRAM OF SECONDARY SCHOOL PHYSICS

A FOUR-YEAR, INDEPENDENT, INDIVIDUALIZED, MODULAR PROGRAM

Louis Deall
Clayton Public Schools
7530 Maryland Avenue
Clayton, Missouri 63105

December 1969

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

Acknowledgements

Acknowledgement is made to two particular groups: (1) To the students who participated in this program for their enthusiasm, eagerness and candor, and (2) To the Clayton Board of Education, who provided the spiritual and material wherewithal needed to initiate and carry-out this program.

Two specific individuals who encouraged and gave the program much imaginative support are Dr. Elmer R. Kane and Dr. William D. Hedges, formerly of the School District of Clayton.

I should also like to acknowledge the help of Mrs. Mary Resnick, who typed and prepared this manuscript.

TABLE OF CONTENTS

APPENDICES

Preface

Most research efforts are concerned with generalizing observed regularities into laws dealing with variables related to a particular set of phenomena. The outcomes are quantitatively predictable. The particular efforts described in this report are more in line with experiment meant as experience. We cannot experiment with children to develop new approaches in education in a detached stimulus-response milieu but rather with the idea of experiencing together; to making softer comparisons to gain new insights. The effects, say, of establishing a closer, more intimate relationship between teacher and studen cannot be evaluated fully by statistical analyses. The central ideas in this project are very different from the approach to teaching and learning found in the mainstream of education. The work, therefore, was more strongly oriented at this time toward development of ideas, techniques, materials, learning structures, and systems, than to theoremization of any particular facets.

Summary

The purpose of this project was to design, build and implement a secondary school physics program that allowed for student variation in individual learning style, mathematical aptitude and topical interests. Some important objectives were: (a) Self paced advancement by the students, (b) Joint evaluation of achievement by teacher and student in a one to one relationship, (c) Individual curricular prescription, (d) Development of independent study capabilities, and (e) Giving up to four years for course completion and study beyond.

The program is divided into four major phases. Each phase is subdivided into topics or units. These are highly structured in the beginning but yield gradually into independent study.

By June of 1970 the program will have been in operation for three academic years. Of the original twelve students, seven have completed. Four of these will take the Advanced Placement Examination. All will take the College Board Achievement Test in Physics. There are fifty-six students currently enrolled and progressing through the various phases. Forty per cent of these would not have taken the regular physics offering. By the fall of 1970, seventy will be enrolled. Twelve students are using advanced materials and are studying the calculus to further facilitate their advancement.

Two main curricular paths have emerged: (1) The more mathematical group which finishes in college level work, and (2) the high school physics group which utilizes a goodly amount of the Harvard Physics Project materials.

Over one hundred topics with sequentially arranged softwares and accompanying hardware trays have been developed. Most of these were redone twice in the light of experience with the students.

Conclusions: The program has succeeded beyond expectations. It will grow as more techniques and greater skills are evolved in student centered methods. People taking physics have more than doubled in number say over five year ago but, more important, their height of attainment has increased in all cases. The program will be continued and further funding should be sought to purchase more advanced apparatus and for increased personnel. From a few trials it is evident that this program would be an excellent vehicle for teacher training, not only because of the close involvement with students but for the program itself.

Further development should also be done in the following areas:

1. Further perfection of the program.
2. Trial of this kind of program in a poverty area.
3. Development of the specialized "short course".
4. Development of this program along interdisciplinary lines that go beyond physics to other sciences and even into other fields.
5. Articulate the later lab work beyond the school confines which will carry students into the community in work related tasks.

Introduction

1. Abstract

The purpose of this project was to design, build and implement a secondary school physics program that allowed for student variation in: (a) Individual learning style, (b) Mathematical aptitude, and (c) Interest in topical aspects of physics.

Some specific objectives were devised to answer the following questions:

1. Could a new program be established which truly fits the individual child as opposed to the one year, monolithic, textualized, lecture-oriented course to which each child must conform?

2. What are the advantages and disadvantages of altering the established "time-duration" patterns by offering 1/4 Carnegie units of Physics in phases for up to a four year period?

3. How is student performance affected by allowing students to pace themselves? What is the value of a student deciding when he is ready to take a unit test, perform an experiment or to advance from one topic to another?

4. How realistic is it to have an open laboratory available all day, fully staffed, with a large percentage of independent study wares?

5. Will the student of high verbal and/or high drive, but of low mathematical aptitude, fare well in a self-paced course in physics?

6. How will highly-motivated, high mathematical aptitude students perform? Will they proceed beyond the minimal course confines?

Brief Description: The program was initiated at Clayton High School in the fall of 1967 to coincide with the beginning of "modular scheduling". It is the nature of this type of scheduling to allow more time for self commitment by the student than is found in the conventional school class format. The laboratory or physics center area is open all day and fully staffed and equipped to help the student when he comes in.

The student works on a topic at a time. The "topic" is the term to denote a single unit or lesson and entails various softwares and instructives along with the necessary hardwares to perform simple demonstrations and experiments. The student takes as long as he needs to complete the topic. When he finishes, he is checked-out by the teacher; after which he goes on to the next topic. There is always a teacher or aide present to help him as he moves along. A group of related topics are called a Level. An example is the Level on Sound which entails twelve topics (See Appendix B). A set of several levels make up a phase. There are four phases (See Appendix A). The first phase has three levels and are highly structured. After each Level a written exam is given. When all of the Levels are completed and the phase is finished, a grade is given to the student thus giving him 1/4 Carnegie unit of credit. Upon completion of all four phases, the course is finished, the final mark being the fourth phase grade. Note that the credit received after the four phases is one Carnegie unit, the same as that received by a student who takes the conventional one year physics course as a junior or senior. In the middle of the second phase the structuring diminishes gradually. The topics now transcend many concepts or cover entire fields. An example is in the second phase, the topic of "Statics" covers equilibrium, Newton's first and second laws, torques, friction, inclined planes and the basic principles of civil engineering. These are pursued semi-independently. By the third phase the student is working wholly independently. Here also there have developed small groups and the teacher is more a member of the team.

2. Comparison with Traditional Approach

The differences between the modular and traditional presentations should be spelled out. As mentioned, the student receives no extra credit. Why should he prefer this approach? What behavioral aspects will be strained or relieved? The major differences are noted:

1. Time Allowance: The student has up to four years to complete the course. He can conclude the course in less time and this has already been done by some. If he is busy with a play or a history paper, he may not come into the lab for over a week. On the other hand, he will have periods when he will be in the lab every day for many modules. He may take over a week to complete a topic with which he has difficulty. By the same token, he may complete one in less than an hour.

2. Nature of the Classroom: There are no scheduled classes of the lecture variety. It was felt that in centuries past the lecture was an advance in mass education. Books and learning materials were scarce or many non-existent. As we enter the latter part of the 20th century, the lecture as the major means of education is no longer acceptable with its assumption of equal concentration by all students, in fact, equating them all to a single individual. It also makes manifest fitting the student to the configuration of a curriculum instead of the other way around. Even when the finest lecturer speaks, one can't help tuning him in and out. In Modular Physics even the usual classroom type of demonstration must be performed individually by the student. Sometimes two or maybe three students will do a topic or portion together. Also in the later phases, groups of two, three or even four will form and meet once a week for some minimal lecture. It is not the lecture itself that is a poor method but a total diet of lectures as the principal offering.

3. Student Teacher Relationship: The most important difference between modular and regular physics is in the nature of the relationship and established rapport between the teacher and student. In modular, it is one to one, student or client centered, and personal. It is based on a dialogue as opposed to the conventional monologue. There is a continual effort to reassure the student in the educational and scientific as well as in those critical personal areas of concern in his learning patterns. Whether reviewing an exam, checking out a topic, or helping in an experiment, it is one individual to another, and not as to a group. In an approach like this, it is not merely a systems or machine oriented approach, but a program based on the relationship and care in diagnosis.

4. Curricular Structure: The curricular structure varies with each individual student. What is prescribed for one will differ from that specified for others. More attention is given to a student's weaknesses as these are identified. One person may be facile say at reading instruments but another may be less adept or inexperienced or even afraid of them. Likewise, greater play is allowed for capitalizing on a student's strengths. This differentiation is particularly noted in mathematical abilities.

In general, two main areas are evolved, as mentioned previously. One, the rigorous more difficult college physics approach, the other was the one more conducive to the so called non-scientific type of the artistic and literary bent. These two are merely general designations as particular topical interests may carry a student into his own unique curricular patterns. Also variations within each phase and topic will be adjusted to the individual student.

3. <u>Use of Funds</u>

A separate expenditure report giving a specific schedule of moneys spent in detail is filed along with this report.

Generally, grant moneys were used as follows for:

1) Equipment and hardware.

2) Assistance in the form of a part-time instructional aide.

3) Planning, devising and writing material for the various topics and arranging the various accompanying hardwares in trays during the summers of 1968 and 1969 by the project director.

4) Audio-visual materials and film loops.

5) Stationery, records and final report.

4. <u>A Description of the Physics Center</u>

The physics center where the program was carried out consisted of a film loop area; two small laboratory areas, a resource and calculation area, and a small, shared darkroom.

A stock room- storeroom was subdivided so that a film loop area, bounded by storage cases for darkening, was at one end. The film is within a case, the upper shelves of which are used to store the film loops. There is room for no more than four students. There is easy access to the screen which often is made by taped-up graph paper so that data can be taken directly from the loop by direct marking. The projector can be stopped at any desired frame. A mounted clock with sweep second hand is on one bordering wall, available as a stopwatch, which is needed with many loops. Many of the storage cases were distributed around the entire lab complex to make room for an auxiliary lab area in the storeroom. In this lab there is a sink, a repair bench, and space where the ripple tank, spectral and various other apparatus are used.

The main lab area is converted from what used to be a large space for say ten groups doing the same experiment. Now, however, we might have ten groups doing differing experiments, there is a modular arrangement of space. Eight stations are used generally; these have versatile water, gas and electrical sources. The latter area has mounted vacuum pumps for studying the gas laws or any application requiring pressure or vacuum. This adjoins a station where permanent rotators are available. Another station along a wall is where a 2.5 meter linear air track is placed along with a large air table. The pucks and accessories are in nearby drawers.

Centrally located is an instrument station having eight places. Here our fine electronic instruments, oscilloscopes, signal generators, power supplies and other accessory electronic gear are located. Finally, there is an electrical experiments lab for doing experiments in electricity and magnetism.

The darkroom is small but the stroboscopic, photographic, and many optical experiments are done here. A great deal of photography work is done and all of it now uses Polaroid camera and film. This is especially true in kinematics and dynamics experiments in conjunction with strobe and air track. A good deal of photography is done with oscilloscopic work, as well.

Thus, it is seen that the space is fragmented and modular and looks a good deal like a commercial laboratory. The above description might lead you to believe that the space available is large. It is actually small and intimate but arranged for people to spread out. Taken in total, it amounts to one and a half regular sized classroom areas.

The resource and calculation area is in the same room with the main lab. Several tables for working problems and studying are arranged near a book shelf area containing text and resource books along with mathematical tables. A Frider. square root calculator is located here for computational work. A computer terminal is also available in another area of the school. Many of the students take courses in Computer Math and use it in physics. A number of topics are designed to assign the kind of tasks that will force the students to learn how to program the computer terminal. What happens to those people not yet trained in its use is that they work with someone who does know how to use it for their particular problem.

In one corner of the lab we have a unique area. Here we have a set of draw-files containing all of the softwares for Phases I and II. Starting with the introduction and Sheet 1 for Topic 1, there follows sequenced in correspondence to the rest of the topics the instruction-sheets, lab-sheets, textual monographs and other paper instructives. Across from these are two Tote Tray Cases containing ninety-six Tote Trays. Each tray contains the hardware and small lab items for a corresponding topic. Thus, a student doing Topic 8 of Level 2, Phase one, takes the software from the appropriate drawer and then takes the tray(s) designated for Topic 8 of Sound to an amenable lab space.

Introduction (Cont'd.)

It should be noted that, say, a football field can be put into a Tote Tray, 19"x13"x4", if a card is placed therein that directs one to the football field. Thus, fixed or larger apparatus are designated both in the tray and in the software directives. An index card of materials for each tray is kept in the tray so that periodic checks will reveal replacement needs. In this area, we also have a desk where students take exams or do work where solitude or isolation is needed.

It should be noted that apparatus, supplies and students are no longer mutually exclusive but are interspersed. Thus, a student has the availability of many materials to not only do the directed experiments but also ones that are self-suggested by questions which arise in the work.

Methods

The Topic: When a student enters the lab for the first time, he is oriented to the laboratory and its procedures and then begins topic number one. Initially then, he draws the material from the Instructives file. These may include an introduction to the material, instruction sheets which describe and direct the doing of demonstrations and experiments, problem sets, and textual materials which are to be read after the topic. He next removes the associated Tote trays that go with this topic, and proceeds to work at a free lab space. The teacher is always close by; he never interferes but interacts on request or if a safety measure is needed. Sometimes he poses a problem, sometimes he helps with the apparatus, but most of the time is spent listening to the student when he needs a forum and particularly reflecting back to that student his own state of learning or even his emotional state. These reflections are aimed at letting the student achieve self insight. They are of the variety such as: "You're confused on this point," or "This point appears to really excite you," or "Where is the source of the sound?"

Some topics require doing problems. Problems show insight into the principles and further elucidates these. Some students will complete a set and hand them in and be checked by the teacher. Others will have difficulty with a particular kind of problem or with the material at hand. Still others have difficulties with all problems. These latter individuals will usually work one problem at a time in the lab resource area and have them checked off individually by the teacher; catching him in between his workings with other students or groups.

The final act in executing the topic is having it checked out by the teacher. This is usually done orally, occasionally written. Sometimes the check-out may be seeing if the student can use a sophisticated instrument (Topic 1 or 5 in Time Level of Phase I). Other times the reporting may be casual and the teacher checks to see if a certain measurement has been made as in the oscilloscopic measure of the Speed of Sound (Topic 6, Level 2, Phase I); or merely if a certain type of calculation such as in determining the specific heat of a metal. Overall, an extended dialogue about the topic completes the check-out. During this dialogue fine points are covered and some instructional areas are covered. An example is in wave-motion (Topic 3, Level 2, Phase I). Here the entire breadth of the subject of waves is gone over. Note that the one-to-one close relationship is highly diagnostic and it is here where strengths and weaknesses are identified to the student. It is also at this point that a joint decision is made to see if the student shouldn't redo some parts of the topic or do connected but different activities if needed. Often associated experiments are devised by the experimenter. A general rule developed in this program and one of its hallmarks around the school is, "If a student asks a question, before giving any answer, ask him to devise a simple experiment which will answer that question.

For example: Does a ball dropped in water or syrup move at constant velocity? Answer elicited from a student: Drop a white marble in a column of transparent syrup using a camera and the strobotac. The resulting picture shows that it does move at constant velocity.

When all concerned are satisfied that the topic is understood and all problems worked, then the student is checked out and he moves on to the next topic. This topic evaluation is not a major crisis but is often casual. Due to the shortage of personnel and the random occasions where everyone wants help and checking at once, an individual may go ahead without being checked. When this has happened, it was discovered later on, usually during the Level exam, that the principles were [illegible] not understood. The check-out of performance and understanding is very important.

Topics in Phase I are highly structured although the student is encouraged to try variations and to devise methods of his own. He is not ready for independent study but occasional threads of this nature are introduced into the latter part of Phase I; topics are planted to begin the development. As an example: Specific heats are measured for ten different substances. The student is asked to investigate the relationship of these values compared to the Atomic weights. It may take a while but he eventually discovers the law of DuLong and Petit. Usually he does this badly but such criticism is given so as to enhance the traits of independent pursuit for the next time. Graphing, using resource books, and their own wits and especially encouraging the use of lateral thinking are developed. The rewards are for self propulsion. The tasks assigned are such as to make the student develop in this way so as to complete these tasks. The first major break comes in the study of Statics in Phase II. Here they are given an entire area with some few suggestions. As the results come in, the criticism and evaluation is slanted so as to stress independence as being desirable. Pointing out what was missed but making allowances for the lack of experience is the main objective. Hopefully, by third phase, all of electricity and magnetism could be done this way. As yet, it is still fragmented into smaller sets or packages.

One last remark about the topics is this -- With the kind of time available, some topics were made into production line investigations. These were in opposition to the discovery type topics. Thus, in doing coefficients of linear expansion of metals, instead of measuring one or two substances, they were asked to measure eight. In doing specific heats instead of the usual measures on aluminum and copper, they did ten including such exotic, previously unmet substances, as molybdenum, antimony, etc. This produced an unusual positive effect among students. In fact, they were often deliriously, joyfully enthusiastic about these topics.

Why this is so is not firmly evident. As conjecture, we find that several performances develops greater skill; allows an expertese to take place; allows a routine performance which rests on previous skills and identifies with professional workers in the field of science. In the ordinary program we are so rushed to advance that every experiment is of the critical learning variety and there is little time to relax and develop one skill well. Those topics and the ones on instruments take more time but produce some intangible desirable effects.

Generally, the topic is the major mechanism in the course. It is a kind of genetic code. It orders the work, the nature of supplies and apparatus and is the basic unit. Conclusions or capping of whole areas are really a linear system of these topics. They not only are the guideposts along the way but references to look back to. These are the modules which yield to the more mature traits and behaviors at the end of the program. It is for this reason that the program is termed Modular Physics not just its association with modular type scheduling.

Phase I

In a physics program which begins at the start of the ninth grade, care must be exerted to do things which do not call for mathematical or scientific skills beyond the student's scope. Therefore, three levels were developed that stressed laboratory skills and which were phenomenological. Level 1, dealing with Time, concentrated on instruments. Topic 1 was concerned only with becoming facile in using the General Radio Strobotac. In addition to measuring motor rotational speeds and linear velocities, it was used to produce animated motion effects and study how things moved at high speeds. After working with this device until he felt that he could use it with facility the student was checked out by: (a) measuring the speed of an unknown motor, (b) measuring the speed of a four bladed unmarked fan, (c) producing a disk which the student must draw to show an animated effect called for by the teacher; and (d) by measuring the vibration rate of a tuning fork having a frequency beyond the range of the strobocscope. The next topic combined use of the strobe with a polaroid camera. The students learned to use them together by taking a picture of a bouncing golf ball and measuring the velocity of the ball from the picture. Some even calculated the acceleration of the ball. Topic 3 used the PSSC experiment I to teach use of hand strobes, bell timers, etc., along with notions of precision, accuracy, range, and sensitivity. Topic 4 dealt with a text on time and had them do a problem set for the first time.

At this juncture many slowed down and enthusiasm waned. Allowing them to go on while still working the problems overcame this slowing effect. It generally is a good technique to change scenery when stalled on a given topic. While there should be no orthodoxy to finishing topic A before allowing one to go on to Topic B; neither should one let it slide by without eventual completions. The final topic in this level is learning to use a Cathode Ray Oscilloscope. This sophisticated instrument is really a glorified clock that extends our time sense down to the micro-second range. It is sometimes argued that instruments like this shouldn't be used until students can understand their inner mechanisms. If this philosophy were followed then no one would be allowed to use an ordinary watch unless he understood the inner mechanism. Initially, oscilloscopes made from inexpensive kits were used. This is a mistake as they are not in proper repair 50% of the time and the instructional staff spends most of their time fixing them. For the last two years two Tektronix scopes were used - a 503 with differential amplifiers and a 561 dual trace, costing $800.00 and $1,200.00, respectively. Despite torturous treatment these have held up. The knobs never fall off, the trigger always fires and the precision is excellent. Many devices can be fashioned from string, chewing gum, and sticks which are excellent teaching devices. But when it comes to critical instruments, one must use very good ones if they're to be used by a large number of students. Voltmeters, signal generators, and power supplies were introduced in topic 5 as auxiliary apparatus. These devices were repeatedly used in studying later topics. For example, the strobe to study vibrations and the scopes in, studying sound and musical characteristics as well as measuring the speed of sound.

Levels 2 and 3 deal with sound and heat. Here every kind of an effect is observed and worked on, whether or not it can be explained at this time. In the sound level, wave motion, the doppler effect, standing waves, chladni plates, in fact, all phenomena are observed. Ripple talks and film loops are also used. In heat, all of the gas law experiments are done in several different ways, along with calorimetery and heat transport. Heat is returned to in the study of Thermodynamics after completing mechanics in Phase II.

Most diagnoses are made by the end of Phase I. The curricular path options are made here. Some students complete the phase by Christmas, other take till June.

Methods (Cont'd.)

Textual Materials: There is no text per se, but the resource area has many books, pamphlets and journals such as "Scientific American". Occasional single sheets appear in many topics and periodic monographs. There are six monographs in sound and eight in Heat. The monograph accompanying a topic is to be read after the experiment is performed. Thus, the primary source of learning is the experiment; the monograph is a hind view which covers material not brought out by experiments. In effect these are fractured texts.

There are fewer monographs in the latter phases because there are many good commercial books and pamphlets which can be utilized and too many written materials by the instructors would tend to disclaim the independent study aspect. Still some few connecting future monographs should be written for Energy, Collisions, and Electricity and Magnetism.

Testing: The evaluative procedures are very different in this program as pointed out previously. Each topic constitutes a mini-exam in a specific area. The exams at the end of each Level are of major standing and are divided into two parts. One is a standardized commercial test on the Level. The other is a test made by the Project Director which entails writing in compostion style about hypothetical situations, scientific projections, and scientific analysis and also including problems and lab performance questions relating to specific work in the topics. Most students take the exam at the "test desk" and set aside an hour period. They may have to leave and return again if more time is needed. Some will take the exam home and work on it for several days. The test is marked by the teacher and each point is gone over with the student individually. These exams are not given to more than one at a time. The effect is vastly different in su h one to one testing. Even the kinds of questions one makes up are different as the grader does not have to deal with twenty papers at once. There is a time to discuss, analyze, project and theorize. There are even items not covered in the curriculum to point up areas of omission. The main idea is to investigate what is known and what should be done about what is unknown and to rectify errors. In the modular part of the test on sound, there were thirty parts. Suppose a student gets eighteen right. Not only are the errors in the remaining twelve cleared up but examined to see whether a pattern exists that indicates portions to be redone and re-examined with new materials.

Some people who seem to be fairly bright but are not scientifically oriented have done very good work but will spend weeks avoiding an exam and impeding their advancement. In one case, the teacher administered the test orally in a discussion manner. The answers were tape-recorded by the student, typed, marked, and then shown to him. He was surprised to see that the responses looked good on paper and were of high quality. Here the limitation to real test validity was the occasional word and comment by the teacher. On the next occasion for an exam there was less stalling and this student took a written exam to begin with. On his third exam the written exam was taken immediately after completing the level. More oral and performance exams will be instituted for Level Tests in the future.

After Phase II, the Harvary Physics Project exam is used by the "High school" group in conjunction with other level exams. The "college group" will use commercial and modular exams, and all of these students will be asked to take the Advanced Placement Physics exam. Four people or more will take them next year. All others will be asked to take the regular College Board Achievement Test in Physics by May, 1970.

Audio-Visual: Many experiments are done by film loops wherein data is taken directly off the screen. These include the Harvary Physics Project Films, the PSSC Ripple Tank Films, and others principally in mechanics. Some local films made on magnetics using the field of the Washington University cyclotron magnet are also used. These loops are best used in conjunction with other aids, experiments, and devices.

As mentioned earlier, Polaroid film is used in stroboscopic, oscilloscopic, and other experiments. That other experimental events are recorded this way is attested to by the fact that over sixty dollars ($60.00) per year is spent on Polaroid film.

The overhead transparency type of projector is used to give instructions for use of apparatus and in electric, magnetic and certain wave experiments by apparatus built for same. It is also used as a measuring device in lieu of a travelling microscope as when measuring optical slits. A measured opaque object (tape usually) is laid on the illuminated platform and the shadow cast on the wall is measured to determine the magnification. Knowing this enlargement factor the slit's shadow is measured by an ordinary ruler and divided by this enlargement factor. Mercury and air columns are also measured this way.

Regular 16 mm sound films are used as well. Particularly the PSSC films. These are ordered from our own St. Louis County audio-visual group periodically. Their arrival and departure are announced and students must arrange to show these to themselves in the school resource center.

Methods (Cont'd.)

Student Records: When a student finishes a topic, he places all materials, problems, photographs, graphs and data in a folder. The folder with his name on it is kept in a file cabinet and is always available to him. Thus, he has a reference source and record of his work. Frequently he will need to use a graph that he made a month previously. An example is the bouncing ball photo made in his second topic. He retrieves this one year later, possibly to study a body undergoing several independent motions and to calculate the acceleration of gravity (also done by film loop and other methods). Even after a single phase the folder can be sizeable and so he eventually eliminates the trivial and keeps what is important.

The teacher also keeps records, of course, the grade book which charts the "check-outs" and topic progress. This is available to the student. The teacher also keeps a record folder that is not available. In this are kept anecdotal remarks, diagnostic remarks, progress reports and various test scores from permanent records. Here also are remarks from parents, counselors, school nurse and administrators.

As noted earlier, time has been spent in developmental and design work and no significant studies or correlations have been worked out. These will be available by the end of the fourth year of this program.

Diagnoses and Treatment: Some students have a fear of apparatus. They are afraid they will break it. It takes time to learn how to relate to apparatus as well as men. The teacher's role is to discern the fears and strengths and to establish a program to allay the former and provide a milieu for augmenting the outcomes of the latter. This calls for a master of the knowledges, attitudes, and skills in physics as well as a reassuring personality. The first year a teacher with a master's degree in physics was the aide for fifteen hours per week. She was bright and intense and one of the best of diagnosticians. She sized up student capabilities and difficulties with penetration. However, she was impatient and easily frightened the students. The next year a boy, a recent graduate, of Clayton who was a student himself with no degree and not knowing as much physics was hired principally to nurse the hardware. He possesses an easy going benign personality and though he is weak in subject matter, he is highly respected and loved by the students. What is really needed is a cross between both -- a person with a good physics background, possessing human insights with a patient reassuring personality. One must not assume from the above that anything goes. One must be firm (but friendly) for safety's sake alone. Also, with no rules, such a laboratory could become a technological lounge or playground.

The balance must be kept in allowing great permissiveness and freedom to work but, at the same time, insisting that time in the lab must be spent working. The simple rules are:

1. Establish a relationship by listening to the student and reflecting back to him his intellectual and emotional state.

2. Constantly give reassurance in areas of difficulty. Respect his efforts.

3. Do not interfere constantly in his work but be available when needed.

4. Be firm about usage of materials and the lab as being a place to work in science and not as a rest home.

<u>Phases II, III, and IV</u>: These phases are outlined on the second page of Appendix A.

Results

Significant Outcomes

As mentioned previously, building and design were the main preoccupations in this project. Getting the program started; producing the materials; packaging, ordering and caring for thousands of items of hardware; and working this into a educational system that was geared mainly to traditional approaches, were the main objectives.

1. Enrollments

   The total number ever enrolled in the program was eighty students. There were fifteen the first year. Of these, seven have finished -- four in the college physics group and three in the high school group. Two moved from the district, one went overseas after completing half of the program, one entered a university after the junior year, two dropped, and three are still in progress. During the second year, twenty-five entered the program but only sixteen of these are still enrolled, twelve are making excellent progress. Thirty-four students entered Phase I at the beginning of this year but only twenty remain. There are six students in the program who are studying on separate plans. They have had a one year course in physics but are going beyond on their own via the lab, but on individual programs. Next year over thirty new students will begin the program. There will be about sixty students in various stages of advancement. It is anticipated that at least thirty-five new students annually will enter at the 9th grade from here on out.

2. The Dropouts

   This program is winding, long and tortuous. It requires the ability to work long range and to develop the characteristics for self propulsion. In the early stages a student was not urged to progress. Of late, it has been recommended that he do minimally a topic per week. Many students take five and six subjects. These, for the most part, are traditional -- daily work is required. The pressure is to do these and leave the physics (where there is no pressure) till later. Many students, under these conditions, prefer the one year course. They dropped almost immediately and showed up later in the one year program. Considering these conditions and the fact that the program is in its experimental stages, it is deemed quite successful. The fact that the rest of the school still operates in a conventional mode, however, places a strain on these students.

Results (Cont'd.)

3. Improvements to Regular Physics

Building a modular physics program with its accompanying laboratory has had an effect on the regular one year program (twenty-eight enrolled this year). Although they use a single text "College Physics" by Sears and Zemansky, their lab is modular and they come in once a week for at least four modules. There is rarely ever more than three regular students in at one time as they are scheduled so as to be scattered throughout the week. Here too many of the demonstrations were performed by the students and almost doubled the number of experiments.

4. The Course Content and Material

Over one hundred topics were designed and arranged. The hardwares and softwares were completed and revised twice. Some twenty textual monographs were prepared. Eight major examinations were prepared and combined with outside commercial exams. Any of the materials are available on request.

5. Materiel

Assemblages, experiments, and hardwares have been arranged along with many apparatus. The repair aspects and organizing have been major problems. Storage has been arranged for easy student access and usage. In addition to coping with the thousands of items there are other problems unique to this operation which have been solved. For instance, a piece of apparatus used to be used on a single day and then put away and stored until a day one year later. A particular experiment now may have to stay set-up for weeks or months as staggered usage by many students is the usual situation. Further, the design is such that a student may work on an apparatus for several mods; leave for another class and return later in the day to work on it again. Consequently, many apparatus and set-ups are out and being used at all times. The appearance of the lab, therefore, is very busy and yields an environment not as sterile as lab desks with everything locked away. It should also be mentioned that items never previously touched by students are now frequently handled hundreds of times per year. These are highly desirable, but costly results. Breakage is high and many items of supply get used up at faster rates. Due to the greater usage the cost per hour used is actually down but total costs are up. This is especially true in the case of the very sophisticated electronic devices.

Results (Cont'd.)

6. Personnel

Increased usage of personnel time has risen exponentially. In the regular class the number of students per teacher is higher but the personal factor is very small. In a larger school, with the proper aids the efficiency factor could be much higher. Many students can work for long periods with little contact help. The important thing is that when they really need it, personal, close-in help is available; the results of such interaction having long lasting effects.

7. Safety

With such a multifacted operation, safety factors are different. There have been no accidents as established procedures for even putting thermonenters in corks have been set and monitored by everyone. Storage for safety, procedures for checking gas and electricity and accouterments such as goggles and the proper clothing are rigidly enforced. Most important is the continued surveillance and presence of staff at all times.

8. Articulation to School

This program goes beyond an isolated science in a corner of the school but should eventually relate to everyone. This has begun as music students have come in to observe sound phenomena. Groups from English and History classes have come in as individuals to observe. We feel that eventually the lab will be a schoolwide and interdisciplinary resource. (See Recommendations section)

9. Atticulation Beyond the School

While still in the experimental stage this program by its very different nature has received public notice (St. Louis Post Dispatch, Globe Democrat, The Physics Teacher, the American Journal of Physics, Croft Publication, and others). Many people in the community and other teachers from some distances have been in to observe and even allowed to work with students and thus get a feel for the ideas. This has bred the conviction that such a free-exchange milieu would be an excellent teacher training ground for two reasons: (1) to get the feel and learn the use of many apparatus and instruments and (2) to work individually with students on specific ideas and topics.

Three papers were presented -- two before physics groups at the 1969 annual and summer meetings of the American Association of Physics Teachers, and one at the 1970 annual meeting of the Association for Supervision and Curriculum Development.

Two other events should be noted here -- the Project Director was awarded the AAPT 1970 Annual Innovative Teaching Cash Award for initiating this program. Also, as a result of this work, he was placed on the National Secondary School Committee of the Education and Manpower Division of the American Institute of Physics.

10. <u>Student Behaviors</u>

Despite a busy and hence strident, cacophonic sound level, many students use the physics source area to work on problems and regular physics assignments, whereas there is an inability to study in the quiet, front-centered, orderly-arranged study hall. When the Friden calculator was kept in a math study hall, it shattered everyone's concentration. It was moved to the physics lab and seems to blend in with the sound level. Here it is easy to concentrate. In the study hall the lack of noise or the physical orderliness is disruptive. Possibly an area with no signle points of concentration and where a variety of work is being carried out helps. Occasionally, however, it must be stark quiet with nothing moving as when a student does the critical portion of a cooling curve experiment. In this case, the cooperation is very good; the student merely requests complete silence for the few minutes involved and gets it.

Some students perfer to work alone, others combine in small groups to do some topics but, in no case, have these become permanent. After a while they are back to doing topics individually. Some students, though, progress together generally. These will form small groups and meet with the Director once a week for, say, forty minutes. This is only done in Phase II and onward. At present, there are five such groups, the largest having four members, the smallest two members. Things of a general nature are covered in these sessions including special problems that arise.

At present, there are only six girls in the program and these are all doing well but are in the high school curriculum. Next year nearly 40% of the entrants will be girls. In the first group, 50% of the students were of the high verbal, low mathematical variety. In subsequent years it was about 40%. This information was ascertained from school records and by conferences with counselors. This 40% is made up of the students who would never have been able to take physics. Many times it is the pace with which new basic concepts are introduced that discourages them. The existence of the program where the approach is leisurely, so to speak, has great appeal. It is felt that these people have learned a gread deal that was not really available to them in the past and so would have been lost to them. They do not drop out in larger numbers than the other type and as large a percentage of these finish the program as do the scientifically oriented ones.

Some students, as mentioned, will work on their own-- with their own course and curriculum assembled jointly with the teacher. These are special cases and have usually completed a one-year program and wish to study beyond.

11. Staggered Admissions

A course usually begins on Day 1 with all students present. Here, the students start in dribbles so that, at any time, there is no clustering at one topic. This makes life livable for instructors and makes for feasible learning for students. Also, in a regular course, if a student comes into the program late in the year even by, say, two weeks, there is much strain for both student and teacher. Many students on learning of this program seek admission and are allowed in at two-week intervals, some entering the program as late as November. These entrants, by petition, are usually very enthusiastic and do well. Often a student has time on his hands if his program is easy and he is one of these bright guile-less children whose power wasn't seen at Junior High School level. Thus, a counselor may recommend admission even as late as the spring semester; for several of these people the program has worked our well.

12. Other Courses

Because the regular time space for a one-year physics course is vacated, the child has room in his rpogram to take other sciences such as Advanced Placement Chemistry, Physiology, or even an extra language or history course.

13. Grades

Test marks have been high for two reasons. A student will redo the work until he has it perfected or else just drops the program without prejudice. There is actually nothing that binds him to the course. No pressures whatever are exerted. The grades to date have varied from the conventional C to A, no failures being recorded but merely being precluded by a drop.

14. Individual Prescriptions

Prescribed instructions that suit the individual have been on the increase. Originally, the design called for a highly structured (more rigid) plan for the first two phases. It was felt that the student at entry is too immature and lacks the necessary knowledge to independently select his learning structure and that as understanding grew, specifications of the program would be turned over gradually (by Phase III) to the student.

As insight into the child is gained, however, slight differences in topic approach and stresses were made in adjustment to his capabilities, weaknesses, likes and dislikes. Soon whole patterns would emerge for some revealing major divergences in individual learning styles. This, in fact, was one of the major items of the rationale in the proposal seeking to initiate this program. (See page two, paragraph 1, of USO Grant Proposal.) Student variations were becoming apparent much earlier than anticipated. A culminating turning point -- the crossroads focus, so to speak, began to be obvious early in the second phase or often at the end of the first phase. These emergent patterns called for completely different approaches to pursuing the remainder of the program. Thus, a complete revision was made of the Phase II material to allow the onset of "independence" earlier than was originally anticipated. The short, insignificant prescriptions made by the staff have by mid-Phase II assumed major trends. It is here that more topics are less confined by specific instruction sheets and allowance made for a broader approach. One example is the incorporation of Harvard Project Physics materials for those with higher verbal and lower mathematical aptitudes. This resulted in completely different over-all plans and topics for these students. The totally different approach was thoroughly discussed with these students before the new plan was set into operation.

15. Background Effect

When a student works on a particular topic, he cannot help but note someone performing an experiment that he is yet to do. Often he studies or tries the apparatus while awaiting check-off of his own topic. This is particularly true for senior level experiments. This prior experience results in faster and better performance when he does arrive at this particular lesson. There is a kind of background gestalt which works in his favor. Occasional working of the apparatus after he has finished that topic helps him achieve a measure of expertese. He is often anxious to show the uninitiated how it works. Again analogous to the industrial lab, a place where constant activity in varying tasks abounds along with discussion levels to match, tempers an atmosphere that is beneficial and educationally effective.

Conclusions

Of primary note is the fact that this program works. In its present state, it is a long, tortuous, but interesting ordeal. A good number have completed the program and many others will do so soon. To the author's knowledge no other program of this type is being pursued elsewhere. It is felt that this kind of a system of learning is many years ahead of its time but holds greater promise for the future than conventional programs which were designed for a century ago.

The Clayton Board of Education is to be commended for backing such a new, experimental approach and should receive further financial help for: (1) Trying new hardwares such as Desk Top Computers and other apparatus; (2) Increasing personnel to expand the program for larger number of students and for further experimentation; and (3) For making studies of a pedagogical nature so as to improve evaluation of results and effects.

Some specific recommendations concerning the program are:

1. Personnel: In light of the program's time demands in the area of hardwares and in personal commitment to working with students, the Director, or Master Teacher, should have minimally a full-time aide. If the program expands, added personnel will be needed.

2. Content: Funds should be sought to continue this study and to complete more monographs, topics, and devices for the later phases.

3. Deprived Areas: This program should be tried elsewhere, particularly in the poverty areas. Most solutions based on the lecture-classroom approach have failed in these schools. The particular nature of this program with its one-to-one, intimate, non-lecture approach should do well with children in hard core deprived populations. Special study should be made first to adjust such a program for any one school and attain agreement by those already working there.

4. Basic Students: Attempts should be made to try these techniques with slow learners, and with people having a language problem, such as in overseas programs.

5. Teacher-Training: The program is an excellent vehicle for teacher training. This conclusion is based on some few reactions by observing teachers. A short internship is recommended for learning use of experimental materials and in working with students.

6. Topic Completion Techniques: The Techniques and methods of a counseling nature which are used to "check-out" the student need to be further improved. This aspect of the training have given us our best results. Teacher time limitations have often negated its benefits.

7. Audio-visual: Further experiment in the personal usage of audio-visual aids by individuals and small groups should be made.

8. Programmed Materials: New materials including programmed structures should be tried from existing available stocks and new ones perfected in the lab.

9. The Short Course: A new type of program has suggested itself and was experimented with. This is the so-called short course. These may be, say, two or three weeks long and be presented in ten topics. There could be some in Instruments, A Study of Sound for Music Students, Electronics, Optical Methods for Biology or Chemistry. These courses are not to serve in lieu of a physics course but for needs and skills in other areas.

10. The Science Bank: The notion of a Science Bank is an extension of the science lab as a resource and library center. The Bank stores sets, assemblages, and studies of materials for a wide number of independent investigations. An example would be a short course, say, on optical mineralogy. The student so interested would come to the Bank and check-out a program, a microscope, a rock and mineral collection, and a kit of tools and materials with which to work on the minerals. At the end of the time, or possibly when he is finished, the materials are brought back to the Bank. This Bank is like a library but checks out instruments, sets, and collections, as well as books.

11. Interdisciplinary Techniques. Interdisciplinary topics should be created. The nature of the program always seems to head this way. A conscious effort should be made to introduce biological, geological, and chemical topics. A study should be made to see whether Language Arts and Social Studies devices should not also be introduced.

12. Junior High Articulation: A similar type of modified modular program in science should be tried in the 6th, 7th, and 8th grade areas. There are many good science programs available that could be adopted. The reason for this is to start to develop the independent and individual approach prior to high school and, of more importance, to capitalize on the wonderful enthusiasm encountered here.

13. Behavioral Studies: A study of the behavioral objectives associated with these topics should be made. Piaget analysis of topics should also be made.

14. Perspectives: A final important result is the establishing of a proper perspective toward the subject. In a regular program, it is a regimen of text and problems. Problems are important but do not give a balanced view. In this program, the student does not meet a problem until the fourth topic. In this way, he sees a balance between experiment, demonstration, reading, speculative activities, problems, and just plain gadgets; the modular arrangement allows many facets to be seen with equal stress and importance. This is a truer picture of the real world of science as well. In later phases, as problems are needed in the development, their number and status increase.

In general, the program did what it set out to do in the areas of "time duration and self-pacing". It also worked exceptionally well in the widely varied terrain of individualization. What was not satisfactorily done was:

1) Completing more and better materials for Phases III and IV.

2) Making the kind of measurements and correlations regarding degree of success and psychological factors. In analyzing also the kinds of anxieties met in science learning situations and devising methods of dealing with them.

These things should be done in the next stage of this Project.

Glossary of Terms

Carnegie Unit: Credit usually given for taking a one year course, such as Freshman English or Chemistry.

Check-Out: Method of reviewing a unit of work with the student.

Demonstration: A modified science experiment wherein no quantitative data is taken, but focuses on a single phenomena. For example: electrostatic effects or expansion effects by heating.

Duologue: Looks like dialogue, but is situation where one talks and the other really doesn't listen. Then the other talks but the former doesn't listen.

Experiment: Standard study of phenomena by taking data, analyzing and theorizing.

Level: A grouping of Topics to cover a particular subject such as heat, sound, energy. Also, see Topic.

Module: The time unit in modular scheduling. At Clayton, all classes are composed of twenty minute modules.

Modular Scheduling: School time system where classes meet at different times for different modules. More uncommitted time allowed to student decision.

Phase: Major division in Modular Physics Program for which 1/4 unit credit is granted on successful completion of 1/4 required work.

Topic: The basic unit for learning segments of the material and for performing tasks. The module or unit in Modular Physics.

Tote Tray: A portable packaged assemblage of a unit of materials or devices associated with a Topic.

Appendix A

<u>The Four Major Phases</u>

Phase I	Introductory and Instruments
↓	
Phase II	Mechanics, Thermodynamics, Fluids
↓	
Phase III	Wave Motion, Electricomagnetism, Electronics
↓	
Phase IV	Modern Physics: Quantum and Relativity

Appendix A (Continued)

The Levels in each Phase

Phase I	Level 1	Time and Instruments
	" 2	Sound
	" 3	Heat
Phase II	Level 1	Matter and Data Analysis
	" 2	Equilibrium - Statics
	" 3	Circular and Trajectory Kinematics
	" 4	Dynamics - Newton's Second Law
	" 5	Gravitation and Astrophysics
	" 6	Collisions: Momentum and Energy
	" 7	Simple Harmonic Motion - Elasticity
	" 8	Rotational Dynamics
	" 9	Thermodynamics
	" 10	Hydrostatics - Hydrodynamics - Viscosity and Surface Tension
Phase III	Level 1	Wave Motion and Physical Optics
	" 2	Electrostatics
	" 3	Currents and Circuits
	" 4	Magnetics
	" 5	Alternating Current - Electromagnetic Radiation
	" 6	Electronics
Phase IV	Level 1	Wave Mechanics
	" 2	Photons and Anti-matter
	" 3	The Hydrogen Atom
	" 4	Electron Waves
	" 5	Solid State Physics
	" 6	Quantum Mechanics
	" 7	Elementary Particles

Appendix B

List of Topics in Phase I

<u>Level 1 Time</u>

1. The Stroboscope
2. Strobe Photography - Poleroid Camera
3. Hand Strobe - Bell Timer - Vibrating Rod Experiment
4. The Cathode Ray Oscilloscope - Time of Flight Experiment
5. Time Text and Problem Set

<u>Level 2 Sound</u>

1. Origin and Sources of Sound
2. Transport of Sound - Longitudinal Waves
3. Wave Motion
4. Musical Sounds - Sound Characteristics - Oscilloscopic Analysis
5. Resonance
6. Speed of Sound
7. Interference Effects
8. Doppler Effect
9. Sound Problems
10. Sound Miscellaneous
11. Sound Exam

<u>Level 3 Heat</u>

1. Fixed Points of Thermometer - Types of Thermometers
2. Linear and Volumetric Expansion of Solids
3. Expansion of Liquids
4. Boyle's Law
5. Charles' Law
6. Expansion of Gases in General
7. Measuring Heat
8. Specific Heats
9. The Freezing Point - Cooling Curves
10. Heat of Fusion of Water - Heat of Vaporization
11. Properties of Vapors
12. Heat Transport and Transfer
13. Heat and Work