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ABSTRACT

Described is a method by which a classroom teacher may apply the systems approach to the development of the instructional segments which he uses in his daily teaching activities. The author proposes a three-dimensional curriculum design model and discusses its main features. The basic points which characterize the application of the systems approach to educational problems are identified. A detailed discussion of the procedures used in the development of an instructional package entitled "Writing Chemical Formulas" is given. Major ideas in this paper are illustrated by several diagrams and a flow chart. The appendix contains (1) a list of the educational goals for Montgomery County Public Schools, (2) a list of objectives for an instructional package, and (3) the hierarchy of objectives for the "Writing Chemical Formulas" unit. Bibliography. (LC)

APPLYING THE SYSTEMS APPROACH TO CURRICULUM DEVELOPMENT IN THE SCIENCE CLASSROOM

by

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The purpose of this paper is to describe a method by which a classroom teacher may apply the systems approach to the development of the instructional segments which he uses in his everyday teaching activities.

In order to place the teacher's lesson development efforts within the proper framework of the overall curriculum development program conducted by the school system, we must first look at the educational goals of the school system as defined by the board of education. Curricular decision-making at this "societal" level results in broad, general, objectives similar to those formulated by the Montgomery County, Maryland, Board of Education. These "Educational Goals for Montgomery County Public Schools" are found in Appendix A.

It is within the bounds of these societal level goals that the administrative and supervisory staff of the school system, with the assistance of the principals and teachers, must develop the "institutional" level design of the curriculum. For several years the curriculum workers of the Montgomery County Public Schools have attempted to design an operational conceptual framework for the development of curriculum on the institutional level. Much of what has been developed to date has been in cooperation with John I. Goodlad of the University of California at Los Angeles, who has served as a continuing consultant in this effort.

The three-dimensional design model which has evolved has systematically organized the various aspects of curriculum design and provided a structure to guide curricular decisions. "Each design identifies the <u>content</u> of the subject or discipline under consideration--the knowledge to be gained and the skills to be taught. It also identifies the developmental <u>behaviors</u> to be practiced by the students as they encounter the content." [1] Within the model these organizing elements (behavioral elements and substantive [content] elements) are constructed as the x- and y-axes of the grid.

The intersections of the behavioral and substantive elements represent the <u>learning objectives</u> which can be organized into specific teaching strategies. These <u>organizing centers</u> provide the unifying structures around which the teacher builds his units and lessons.

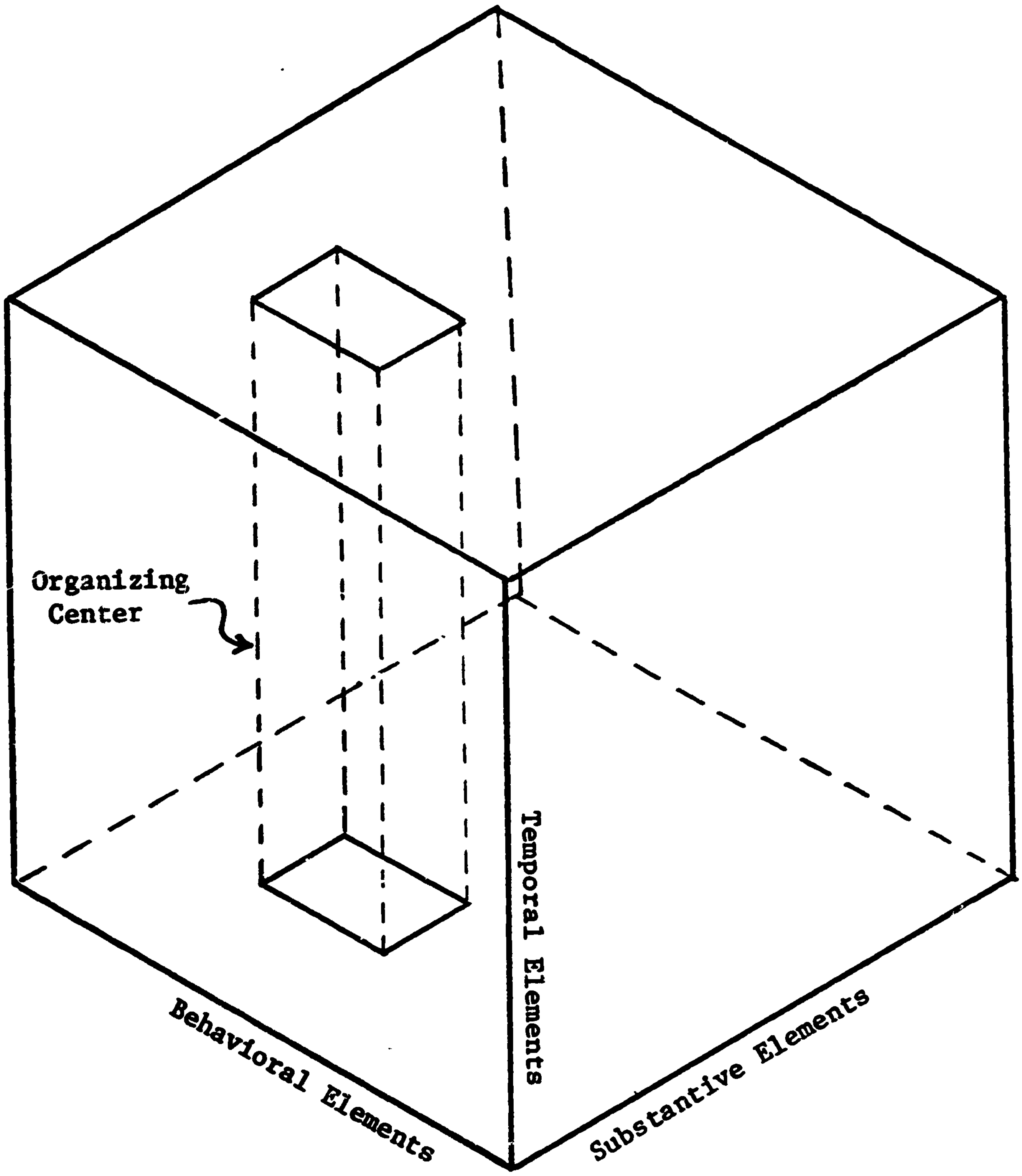
The third axis of our model is a time, or grade level, axis. Progressing upward along this axis for a given organizing center reveals an increase in the complexity of the concepts which is commensurate with the intellectual capabilities of the student for each of the grade levels. In this way, the model not only defines specific learning objectives, but, through the use of the organizing center, also provides a unifying link to the objectives for grade levels both above and below that where the learning objective in question has been placed. It is here where the "instructional" level curriculum development takes place. A representation of an organizing center within the model is found in Figure 1.

Now that the general framework for curriculum development has been outlined, let's briefly describe the "systems approach" before we look at the activities in which a classroom teacher would engage as he develops curriculum on the instructional level.

The systems approach may be described as a highly-organized, well-defined, systematic method of problem solving. Many people believe that it is simply common sense applied to the nth degree. Or you may wish to describe it as a scientific method for the investigation and solution of problems. As applied within this paper, the systems approach is a process by which the classroom teacher may bring about change in the instructional program in which he is engaged.

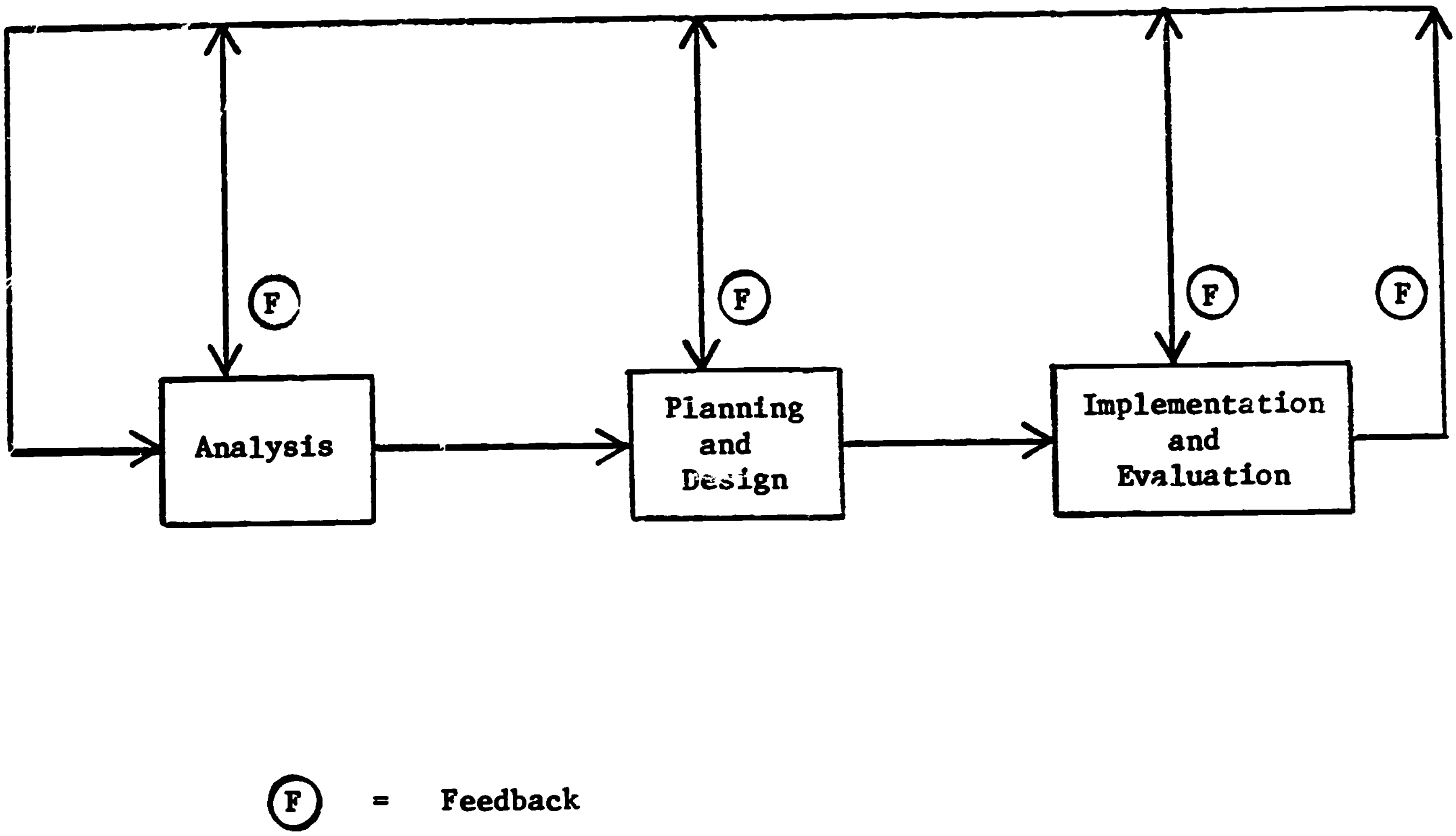
Changes in the instructional process are accomplished in three basic steps, or phases: (1) analysis; (2) planning and design; and (3) implementation and evaluation. In flow chart form, the basic phases would appear as in Figure 2. [3] In each of the phases, feedback is a critical factor. Provisions for feedback at key points throughout the three phases of the process are essential to the determination of the success or failure of the process to attain the specified goals for these points.

A more specific description of the systems approach as applied



MCPS Model for Curriculum Design

Figure 1



Basic Phases in the Systems Approach

Figure 2

to education was formulated by Task Gro-- "I of the Project ARISTOTLE Symposium. [4] Eight basic points which characterized the typical application of the systems approach to educational problems were identified and described in great detail. A summary of these eight points is as follows:

1. State the real NEED you are trying to satisfy.
2. Define the educational OBJECTIVES which will contribute to satisfying the real need.
3. Define those real world limiting CONSTRAINTS which any proposed system must satisfy.
4. Generate many different ALTERNATIVE systems.
5. SELECT the best alternative(s) by careful analysis.
6. IMPLEMENT the selected alternative(s) for testing.
7. Perform a thorough EVALUATION of the experimental system.
8. Based on experimental and real world results, FEEDBACK the required MODIFICATIONS and continue this cycle until the objectives have been attained. [4]

At this point a comparison of these eight points with the three basic phases mentioned earlier may be of value. The statement of the need and the definition of objectives and constraints (Points 1, 2, and 3) occur within the analysis phase. At the end of this phase the existence of a problem has been recognized, the modifications necessary to solve the problem have been identified, and the demands upon the system in terms of money, time, and energy to be expended have been calculated.

Generation of alternative systems and the selection of the best alternative (Points 4 and 5) are elements of the planning and design phase. The results of this phase project the probable effectiveness of the proposed modifications and the further changes which should occur before implementation. Points 6 and 7 obviously are found within the implementation and evaluation phase. Within this phase the validity of the change is determined and a comparison of the new method with the previously used way of accomplishing the same objectives is conducted. At the end of this phase a judgement as to the overall success of the change is made.

Revisions and modifications of the program are identified throughout each phase on the basis of the feedback (Point 8) provided by the system.

Using the eight points listed above as a checklist, the teacher can develop a model for identifying and solving the problems which he encounters within the instructional program. The model which he develops whould provide a method for stating a problem, proposing a solution to the problem, and implementing and evaluating the proposed solution. Whatever form this model may take, it must provide an organized method for solving problems and <u>must</u> <u>not</u> place restrictions on the teacher which hamper his attempts to attain his stated objectives.

Let us now turn to a model for developing curriculum on the instructional level and use as an example the development of an instructional package which I constructed for use within the Montgomery County Computer-Assisted Instruction Demonstration Project. While this lesson has been developed for implementation within a CAI system, the procedures for development which will be described are general enough to fit any type of lesson development.

As the teacher begins to devise an instructional sequence (engages in curriculum development on the instructional level), he finds that many general goals have been already defined for him in terms of the societal level goals of the board of education and the institutional level goals set by the curriculum workers within his school system. These institutional level goals may be in the form of a curriculum design, or model, such as the one mentioned earlier, or, perhaps as more commonly found, a course of study.

Within the curriculum design for science of the Montgomery County Public Schools are found a manageable number of substantive and behavioral elements which form the basis of the curriculum model for science. (See Figure 3.) The five major substantive elements which have been identified are:

1. The nature and structure of matter.
2. The nature of energy.
3. Physical interactions.
4. Biological processes and interdependencies.
5. Cultural, social, and technological implications of science.

SUBSTANTIVE ELEMENTS \ BEHAVIORAL ELEMENTS	1. Observing events and using symbolic forms.	2. Relating and developing event meanings.	3. Investigating meaning and relationship.	4. Restructuring events.	5. Acquiring attitudes and values.
1. The nature and structure of matter.	*	*	*	*	*
2. The nature of energy.	*	*	*	*	*
3. Physical interactions.	*	*	*	*	*
4. Biological processes and interdependencies.	*	*	*	*	*
5. Cultural, social, and technological implications of science.	*	*	*	*	*

*ORGANIZING CENTERS

SUBSTANTIVE AND BEHAVIORAL ELEMENTS
OF THE MCPS SCIENCE DESIGN

Figure 3

Five major behavioral elements have also been identified:

1. Observing events and using symbolic forms.

2. Relating and developing event meanings.

3. Investigating meaning and relationship.

4. Restructuring events.

5. Acquiring attitudes and values. [1]

These sets of behavioral and substantive elements, together with the four levels on the time axis, comprise the three dimensions of the science design model. Each of the elements has been formulated on the basis of its relationship with the educational goals established by the board of education.

On Level IV (Grades 9-12) the intersection of the behavioral element, "Observing events and using symbolic forms," and the substantive element, "The nature and structure of matter," forms the organizing element:

> The properties of substances are related to the kind, number, and arrangement between atoms, molecules, and/or crystals of the substance. [1]

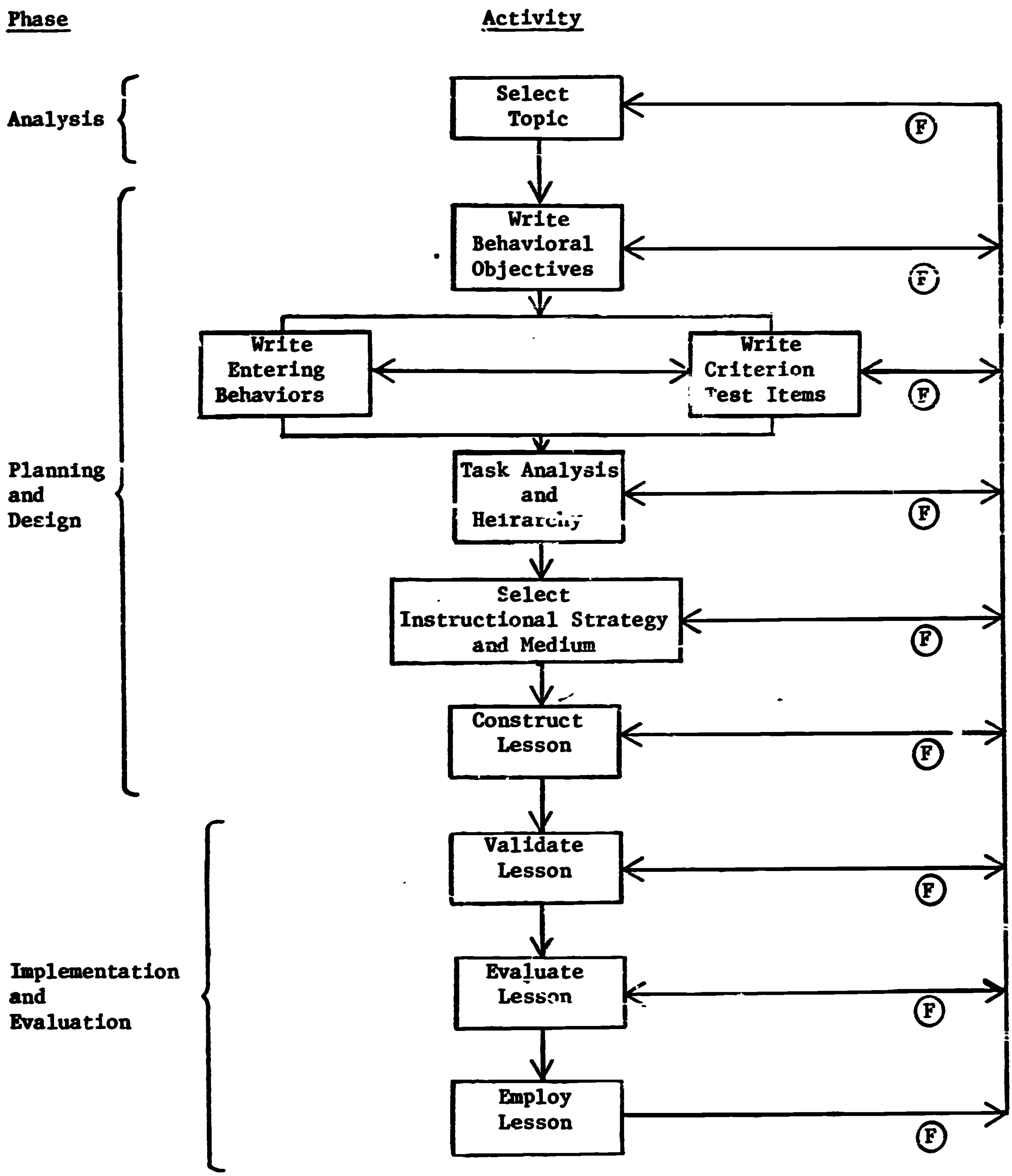
Employing this organizing center within a high school chemistry program would necessitate the development of many specific instructional objectives in order to attain the goals of the center. One of these instructional objectives would certainly involve the writing of chemical formulas to represent the kinds, numbers, and arrangements of the particles within compounds.

What we have just done is the first activity of a model for the development of an instructional package, the selection of a topic. Criteria for the selection of the topic may vary greatly, but almost always involves the identification of a problem area. Are the students experiencing difficulty in achieving the desired behaviors? Does the teacher feel that the current method of presenting this topic needs improvement? Does the course of study require that a given topic be included in the program?

After the topic has been selected, a systematic procedure for developing the instructional package should be followed. A procedure which I have found to be effective includes the following steps:

1. Select the topic.
2. Write behavioral objectives.
3. Write entering behaviors.
4. Write criterion test items.
5. Perform task analysis and construct heirarchy.
6. Select instructional strategy and medium.
7. Construct lesson.
8. Validate lesson.
9. Evaluate lesson.
10. Employ lesson.

The relationships among these steps are represented in flow chart form in Figure 4.



MODEL FOR CURRICULUM DEVELOPMENT
ON THE INSTRUCTIONAL LEVEL

Figure 4

Writing objectives for the lesson in behavioral terms is necessary in order to provide a measureable outcome which can be used as a criterion for the attainment of the desired goals. By specifying in very explicit terms the behavior which the student is expected to exhibit, a means for measuring the success of the instructional package is assured. An objective within the formula writing package expresses exactly what the student is expected to perform:

> Given the name of a simple, inorganic compound, a list of common elements and their chemical symbols, a list of common radicals and their formulas, and the oxidation numbers of each, the student will be able to write the chemical formula of the compound.

The above terminal objective is one that the student is expected to exhibit at the end of the instructional sequence.

Once the terminal behaviors for the lesson have been stated, the teacher may begin work on one of the two branches which occur in the model at this point. The sequence of the next two activities is not important, but both must be completed before progressing further through the model.

In order to measure the student's attainment of the lesson's objectives, criterion test items which measure the desired outcomes of the instruction must be written. When writing these test items, it is helpful to write more items for each objective than are needed within the lesson. This will enable the teacher to select randomly those items which are placed in the post-test which measures the student's achievement.

Students who have attained the desired behaviors prior to the instruction must be identified through the use of a pretest. (These students do not need the planned instruction.) Questions on the pretest may also be selected randomly from the pool of test items which have been constructed for each objective. A properly constructed criterion test item is usable in both the pretest and post-test.

A pretest may also be used to identify those students who have acquired the behaviors necessary to entry into the lesson. The employment of student entering behaviors is a requirement for the identification of those students in the target population for the lesson. Before a student begins an instructional segment, he must provide evidence that he has acquired the behaviors which are prerequisite to that lesson. At this point the teacher may find it convenient to write test items for the entering behaviors which he has identified.

Now that the teacher has indicated the student's current level of attainment by constructing the entering behaviors and has specified the goals of the next lesson by stating the terminal behavioral objectives of the lesson, he must determine by performing a task analysis the method by which the student will span the gap between entering behaviors and terminal behaviors. Exactly what is the step-by-step method by which an objective is achieved? This task analysis may be represented as a heirarchy of entering behaviors, terminal behaviors, and enabling objectives.

Those intermediate objectives which must be achieved in the step-by-step progression through the heirarchy are called enabling objectives. They "enable" the student to acquire the terminal objectives. An example of an enabling objective within the formula writing package is:

> The student will be able to calculate the sum of the oxidation numbers of the elements comprising the compound.

The heirarchy and the objectives for the instructional package, "Writing Chemical Formulas," are found in Appendices B and C.

The task analysis which has been performed will prove to be extremely helpful in the next step of our model, the selection of an instructional strategy and medium.

Before moving on to that step, let's look at the feedback function of the model. With each new step that the teacher has completed, he has developed more fully the conceptual scheme of the lesson. This fuller development of the lesson enables the teacher to better evaluate his progress to date. The feedback loops within the model provide a means by which the teacher, on the basis of a current discovery or enlightenment, may return to previously completed steps and revise them in terms of the newly uncovered information. When constructing a heirarchy, it is common to find that an essential entering behavior has not been previously stated. The feedback loops provide the means by which the teacher goes back to modify the original entering behaviors.

Use of the feedback provisions enables the teacher to make modifications throughout the lesson development at the point at which a necessary modification has been identified. The process of change within the model is continuous and provides a greater flexibility in the lesson development.

Selection of an instructional strategy and an instructional medium may be based on many criteria. To simplify the decision, the primary consideration for selection is what available strategy and medium will best present the lesson. The type of learning involved and the capabilities and learning styles of the student are of upmost importance in the selection. However, the constraints of available time, energy, and money place restrictions on the lesson development. For this reason the teacher must select the best available instructional system.

Construction of the lesson not only includes the actual writing of the planned instructional sequence, but, also the development of any instructional materials needed within the lesson, including the pretest and post-test to be used in conjunction with the lesson. At this point difficulties in constructing the lesson may necessitate a revision of any one (or more) of the previously completed steps.

Within the development of the formula writing lesson, it was noted that many of the enabling objectives were relatively simple and that students may have already acquired these behaviors. The pretest which was constructed was diagnostic in nature and the results were used to prescribe for each student an individualized lesson which included instruction on only those objectives which he had not yet acquired.

In other cases the objectives of the lesson may be of such a unique nature that there is little chance of the student acquiring the behavior prior to the lesson. For this type of instruction a highly individualized lesson may not be as desirable.

A lesson which consists of a drill and practice routine may provide the same basic drill for all students. Individualization within this type of lesson may be in the form of the amount of drill prescribed for the student. Ideally, the student receives only that amount of drill necessary for him to become proficient in the skill which he is practicing.

Once the lesson is constructed, the teacher must validate the lesson. Does the lesson actually teach what it is intended to teach? Validation schemes vary depending on the instructional strategy involved, but in all validation plans is the use of a post-test which contains the criterion test items for the objectives of the lesson. The student must demonstrate that he has attained the objectives by passing the criterion test. The standards for passing the test must be set by the teacher before the initial student tryout is conducted.

Analysis of the student performance will enable the teacher to determine if the lesson does teach what it has been designed to teach and, if not, what revisions are necessary before the lesson is considered to be valid. This process of tryout and revision is repeated until the lesson produces the results which the teacher has set for it.

Following the development of a valid lesson, a comparison of its use with the use of the previously employed instructional strategy must be accomplished. Although the lesson is valid, it may not produce as good a result as other available means of achieving the same objectives. Again a series of tryouts and revisions may be necessary to complete the development of a lesson which not only produces the desired behaviors in the students using the lesson, but also produces better results than other available means.

Now the lesson may be applied on a class-wide or school-wide basis. However, the curriculum development is still not complete. Through the employment of the lesson the teacher acquires a much greater base of data upon which decisions for change in the lesson may be made. The curriculum development process is a continuous one and the teacher must not be satisfied with the status quo.

One question that the teacher may ask concerning this model for curriculum development is,"Where do I get the time to perform all of these tasks?" Many of the activities are quite similar to those required in the writing of lesson plans. Others will require additional time on the teacher's part, but any teacher who is concerned with the effectiveness of his teaching and the achievement of his students will find this model to be useful in planning and developing more effective instructional sequences.

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APPENDIX A

EDUCATIONAL GOALS FOR MONTGOMERY COUNTY PUBLIC SCHOOLS

1. Competence in the fundamental skills of listening, observing, speaking, reading, writing, spelling, mathematics, and the arts.

2. Recognition of and respect for the worth of each individual.

3. Appreciation for and power in logical, critical, and creative thinking.

4. Understanding and acceptance of the responsibilities and appreciation of the privileges inherent in the American way of life.

5. Understanding and evaluations of the cultures and contributions of other peoples.

6. Understanding of scientific truths of the universe and man's relationship to them.

7. Effective human relationships for democratic living, as they apply to the individual in the family, in the school and community, in the country, and in the world.

8. Wise use of human, natural, and material resources.

9. Competence in choosing and pursuing a vocation.

10. Respect for and pride in good workmanship.

11. Values in aesthetic appreciation and creative expression.

12. Ethical behavior based on moral and spiritual values.

APPENDIX B

WRITING CHEMICAL FORMULAS

Objectives

At the end of this lesson, the student will be able to:

1. Given the formula of a compound, state the chemical name of the compound.

1a. Given a chemical formula of a compound and a list of names and the symbols of the chemical elements, identify those elements present in the compound from the symbols used in the formula.

1b. Given a chemical formula of a compound and a list of names and the formulas of the common radicals, identify those radicals present within the compound.

2. Given the name of a chemical compound, write the formula of that compound.

3. Write the lowest set of integers which gives a net oxidation number of zero for the compound as subscripts following the appropriate symbol or radical.

4. Select a set of integers which, when multiplied by the number of moles of each element and/or radical within the formula, will give a net oxidation number of zero.

5. Interpret a sum of zero for the oxidation numbers of the elements within a formula as an indication that the formula is correctly written.

6. Calculate the sum of the oxidation numbers of the elements comprising the compound.

7. Calculate the number of moles of each element that comprises a radical within a compound by multiplying the number of moles of each element within the radical by the subscript following the parentheses which enclose the radical.

8. Indicate the presence of two or more moles of a radical within one mole of the compound by enclosing the formula of the radical in parentheses and placing outside and following the parentheses the subscript which numerically equals the number of moles of the radical present.

9. Interpret the subscript following a chemical symbol or radical within a formula as indicating the number of moles of that element or radical within one mole of the compound.

10. Write the element or radical with the most positive oxidation number first (leftmost) in the formula.

11. Write the element or radical with the most negative oxidation number last (rightmost) in the formula.

12. Define a chemical radical.

13. Define a formula as representing one mole of a chemical compound.

APPENDIX C

Heirarchy
Writing Chemical Formulas