The Federal Government creates and disseminates large accounts of technical information in various forms, i.e., handbooks, manuals, guides, texts, brochures and periodicals. Much of this information is of value to the vocational-technical secondary school teacher for updating lessons and giving information which keeps pace with occupational changes. This study was conducted to "Determine the Feasibility of Developing a Model Describing the Flow of Occupational and Economic Information into the Secondary Vocational-Technical School." The study went beyond this to produce quantitative models which describe and measure the utilization of government-published data. It was also expanded to include the comprehensive secondary school as well as the vocational-technical secondary school. (Not available in hard copy due to marginal legibility of original document). (NH)
Systems Engineering of Education VIII:

QUANTITATIVE MODELS FOR OCCUPATIONAL TEACHER
UTILIZATION OF GOVERNMENT-PUBLISHED INFORMATION

Leonard C. Silvern and Carl N. Brooks
The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgement in the conduct of the Project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. Office of Education
Bureau of Research

Contract No. OEC-9-9-140152-0003(057)
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The following faculty and staff at the University of California-Los Angeles examined, reacted and contributed to the ideogram in section C-Analysis, 1-Flowchart Model:

- Dr. Miles H. Anderson, Director, Clinical Instructor Training Program, Division of Vocational Education.
- Dr. Robert W. Hayes, Director, Institute of Library Research.
- Dr. Richard L. Lano, Supervisor, Trade and Technical Teacher Education, Division of Vocational Education.
- Miss Mary J. Ryan, Head, Public Affairs Service, UCLA Library.

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- C.W. Branch, Dean, Richland Technical Education Center, Columbia, South Carolina
- M.R. Clark, Superintendent, Area One - Vocational Technical School District, Calmar, Iowa
- J.F. Collins, Director, Weymouth Vocational Technical High School, East Weymouth, Massachusetts
- B.O. Compton, Dean of Instruction, Technical Education Center, Sumter, South Carolina
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<tr>
<td>A.P. Wood</td>
<td>Vocational-Technical Curriculum Specialist</td>
<td>School District of Kansas City</td>
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Leonard C. Silvern
Principal Investigator

Carl N. Brooks
Associate Investigator
A. INTRODUCTION TO PROBLEM

1. Background Study

In December 1966, the U.S. Office of Education contracted with Education and Training Consultants Co. (ETC), Los Angeles, to "Determine the Feasibility of Developing a Model Describing the Flow of Occupational and Economic Information into the Secondary Vocational-Technical School" (1).

The study was completed and submitted to the Commissioner of Education in June 1967. The study went beyond the original proposal and developed a flowchart model. In addition, it was expanded to include the comprehensive secondary school as well as the vocational-technical secondary school. In order to improve dissemination of the systems engineering conceptualization inherent in the project, ETC published it with the title, "Systems Analysis and Synthesis Applied to Occupational Instruction in Secondary Schools," in November, 1967 (2).

a. Conceptualization of a Model

In the study, a flowchart model was synthesized having 49 separate and distinctly identifiable feedback loops. A rigorous definition of "feedback" was established based upon closed-loop control systems theory rather than on the less stringent meaning implicit in non-physical systems applications.

This model is a high-fidelity analog of teacher relationships in real-life. It is a cybernetic model which relates the occupational teacher with the real-life environment outside the school subsystem. It is from this real-life domain that information is received and to which graduating students are sent. A simplified model appears in Figure 1. It is delineated at the first or major level of detail. The complete model will be discussed later.

Both student and teacher are subsystems within (4.0). Students leave a secondary school by graduation or as dropouts and enter employment (1.0), enter an institution of higher education (3.0) or perform military service (2.0). Non-employment is not specifically depicted but may be regarded simply as state two of the two-state subsystem (1.0).

At some point in time after leaving secondary school (4.0) they will also leave the military (2.0) and college (3.0) subsystems for employment in business, industry and government (1.0). It is virtually impossible for a particular person leaving (4.0) and entering (1.0), (2.0), or (3.0) to return to the same (4.0) environment. Thus, any inputs to (4.0) from outside, due to this time continuum, will affect younger students and not the original students. The model describes functions and the interrelationships and not individuals per se.

However, while the flow is discrete at the atomic level, it may be viewed as continuous at the molecular level. Certainly, the occupa-
tional teacher performs as a continuous function and it is this function within (4.0) which is identified in Figure 1. The conventional electrical signal analog applies exactly. (4.0) has more signal inputs than any other sub-system, 10 to be precise. While there are many feedback signals in the complete model, (4.0) has 8 major feedback inputs.

Figure 1 - Flowchart Model Developed in Initial U.S. Office of Education Study by ETC at the First Level of Detail.

Subsystem (10.0) produces feedback to (4.0) generally in the form of information obtained from employee and trade association magazines, brochures, meetings, etc. Such data is supposed to add to an instructor's knowledge bank and thereby modify his behavior. The information in (10.0) is obtained in part from various surveillance or early warning sensors operated by associations and societies (8.0).

The same surveillance data (8.0) also influences (9.0) and is translated into recommendations and policies by advisory bodies at various levels. At the macro level, information is transmitted to the State Department of Education (7.0). At a lower macro level, it is transmitted to the school district, and at an even lower macro level to the occupational teacher in a particular secondary school of the same school district (4.0). (9.0) obtains information from (7.0) and both information and manpower (members) from (1.0).
Professional societies (6.0) also perform a surveillance function (8.0) and use any feedback to control their outputs and thereby stabilize that loop. This is accomplished through meetings attended by teachers (4.0), recommendations for licensing (or non-licensing) and curriculum requirements transmitted to (7.0).

The State Department of Education (7.0) uses (6.0) and (9.0) information as feedback to control its output but one signal input from (11.0), namely federal and state tax dollars, has a profound influence. At the regional level where programs are operated to reach an occupational teacher (4.0) directly, feedback from real-life is most often embodied in the form of experienced managers and supervisors in (1.0) who instruct in (12.0) and also may have a role in contributing to the selection of occupational content for training programs (7.0).

It is the tax-paying citizen (13.0) who inputs his dollars to (11.0) which go to (7.0) at the state level and to a particular school or school tax district (4.0) at the local level. (13.0) acting as a non-parent, can create and apply pressure to the management of a district in various ways (4.0). (13.0) rarely has acted as a parent in this role, but organized parent action groups outside of the PTA variety are beginning to emerge as a powerful force in certain geographical areas.

Occupational instructors look more and more to state colleges, community colleges, junior colleges, and non-public trade schools (12.0) to obtain information used as feedback to correct errors and control their output (4.0). These institutions face the same problem of presenting updated information, thus error-correcting feedback enters (12.0) in the form of experienced managers, supervisors and technical employees from (1.0).

Because of great academic freedom for the individual teacher in higher education, feedback enters (12.0) from (5.0) as vendors furnish in-service training which invariably focuses upon the products being produced in (5.0). To a lesser extent, internally generated research and development in occupational materials and methods may reach the continuing education function (12.0) and eventually be transmitted to (4.0).

Occupational instructors rely upon resources (5.0) and the information generated to update their content and, as feedback from real-life, to alter their outputs. There are minor signals to (5.0) from (6.0) which consist mainly of the provisioning of mailing lists for vendor advertising. Major signals to (5.0) from (6.0) consist of state-administered tests used for licensing or other purposes.

In terms of national practice, subsystem (14.0) is undoubtedly the least significant. It consists of job experience obtained by an occupational teacher instructing at a junior college or college and reviewing books and manuscripts for publishers. The most significant is (1.0) which describes job functions in business, industry and government. Students from secondary school enter (1.0) and spend 25% of their working lives there, over a time period of 45 years (20 to 65). Error-correcting feedback from (1.0) to (4.0) may be in a variety of forms: supervisory instruction to students engaged in cooperative, work-study programs, supervisory instruction to teachers employed either in a special program or randomly, information channeled through social or leisure-time activities from employees to teachers, information transmitted
b. Characteristics of the Model

Five characteristics are identified with the information processed in the model, Figure 1.

1. **Frequency (f):** nature or rate of information flow; a measure of the continuiness of information using as a unit one semester of secondary school; the frequency of information fed back to an occupational teacher could be high, moderate, low or zero;

2. **Entropy (H):** order and organization of information and the signal path and information flowing through it in terms of order-disorder; the entropy of information and/or path could be high, moderate or zero;

3. **Figure of Merit (M):** usefulness of information without alteration; a measure of the percentage of information usable by an occupational teacher so he may integrate it into a unit, sub-unit, lesson, teaching point, or step; the figure of merit of information fed back to an occupational teacher could be high, moderate or zero;

4. **Reliance (R):** changes in information content during transmission and at reception; a measure of the percentage reliability based on the absence of noise, distortion, data transmission errors (bits), etc. which change the information meaning so an occupational teacher will receive information different than originally generated at a source; the reliance of information fed back to an occupational teacher could be high, moderate or zero;

5. **Recency (t):** age of information at reception; a measure of the time elapsed from transmission to reception, the transmission time using as a unit one semester of secondary school; the recency of information fed back to an occupational teacher could be high, moderate, low or zero.

Forty-nine closed-loops are identified and each is described in terms of these five characteristics. From this, an evaluation statement is made concerning the value in pursuing or abandoning the loop under discussion.

c. Conclusions, Implications, and Recommendations

In gross terms, the teaching performance (P) of the occupational teacher may be expressed as:

\[ P = f(f, H, M, R, t) \]

The model has these characteristics:

1. It is a high-fidelity analog of real-life;

2. It is a cybernetic model, showing interaction with a real-life environment;
(3) it is closed-loop with a large number of feedback signal paths, extrinsic and intrinsic to the school or school district;

(4) it is a general model of secondary schools and of occupational teachers in those schools;

(5) it has closed-loop feedback signal paths each of which is identifiable in terms of up to five characteristics;

(6) it appears possible to measure the value of each feedback loop in crude units;

(7) instructor performance (P) dealing with the inputting of updated information is a function of \((f, H, M, R, t)\).

The most efficient method of measuring the effectiveness of occupational instruction is to examine conventionally the activities of program graduates in their jobs. However, this can prove to be impractical if the overall purpose is to improve occupational instruction rather than merely statistically examine employment outcomes. The study reveals that the interface between teacher and student was extremely critical since it is at this interface that communication occurs and information in the mind of the occupational teacher is transmitted to and received by the student. If we are interested in the method of instruction, per se, then we would wish to study the signal path itself. However, if the interest is in the content being instructed, in terms of updatedness, then we must study the information being transmitted.

The study concludes that the occupational teacher's performance is related to frequency, entropy, figure of merit, reliance, and recency as defined. This may be interpreted to mean that variations in these characteristics could alter teacher performance. Assuming that the method of instruction was suitable and satisfactory, students would receive far better information than at present.

Using this logic, if it is possible to quantify the flowchart model using one or more mathematical models, then an occupational teacher in a secondary school could be measured and his performance determined. However, his entire performance would not be so measured. Only that aspect of his performance which dealt with occupational content would be delineated.

This has become a major problem in education today since technology in the real-world is causing so many changes in jobs that it is becoming a major headache to the occupational teacher who wants to keep up but is unable.

Such mathematical models would provide a uniform instrument for measuring occupational teacher performance in any school district. They would allow comparative analyses to be made. They would identify courses in schools which were outdated and would tend to improve and maintain the experience of the occupational teacher. He would have a measurable whole which he could utilize to justify obtaining additional assistance from his school and school district management.
The school and school district management would be more responsible for updating and maintaining the updatedness of course content which presently is delegated to the teacher or ignored completely. This applies largely to existing occupational courses and teachers.

For those districts engaged in developing new comprehensive schools, and for those involved in new vocational and technical curriculum development, it would be of inestimable value since the measurements occur at the very beginning and the models require that workable, closed-loop signal paths be created in fact rather than on paper.

The model may be viewed from the outside in. Improvement of present methods of transmitting information into the schools from sources outside would be most welcome by these sources. For example, if a generator and transmitter of information finds that virtually none of it is ever retransmitted by occupational teachers to their students, an investigation of the breakdown in communication would be warranted. This might suggest that existing methods based on the past are ineffective and a completely new and innovative technique be synthesized.

The basis for such a decision would be the measurements made through the use of the models and the basis for the synthesis of new techniques would be localized to those areas of the non-model; i.e., where signal paths feeding back information to the occupational teacher do not exist at all.

2. Selection of Subsystem (5.0) PRODUCE RESOURCE MATERIALS & SERVICES

In essence, the initial study (OEC-4-7-061544-1601) and the one reported in this document (OEC-9-9-140152-0003[057]) view the system ideographically as an information processing network in which the occupational teacher accumulates information, sorts and retransmits it to students through classroom, shop and laboratory instruction. The students are expected to transfer this to jobs. When this sequence of events is accomplished at a high level of proficiency, the students are more acceptable and useful in the real-life world of business, industry and government. Their employability index is higher.

In discussing employability, it is assumed that general or academic education as commonly defined has also been acquired. The function of the occupational teacher is performed to complement the activities of the academic teacher who dispenses general education. Also, the occupational information used by a teacher for guidance purposes is considered outside of the domain in this discussion.

The 49 feedback loops were examined and those having a high probability of success in yielding to quantification were identified. The loop (5.0)→(4.0)→(1.0)→(4.0) was selected and may be traced in Figure 1. Selection was based upon the characteristics of low frequency, high entropy; figures of merit, reliance and recency which were degraded by high entropy; and specific recommendations for expansion of the loop.
Subsystem (5.0) is the function producing resource materials and services which enter the PROVIDE HUMAN INSTRUCTION (4.6) subsystem and influence the course content ultimately transmitted to the student. As seen in Figure 2, the original (5.0) subsystem contained 10 subsystems.

![Figure 2 - The Original PRODUCE RESOURCE MATERIALS & SERVICES (5.0) Subsystem](image)

The major generators are the government (nominally the federal government), manufacturers of hardware (physical products or materials used in product manufacture), and vendors of such hardware (manufacturers, distributors, proprietors). Because the typical occupational instructor is isolated from real-life in the sense that he is employed by a school district, one major source of information dealing with the content of his occupation would be (5.0).

Not all of the generators of resource materials and services are identified in (5.0). Only those clearly identified through interviews conducted in the initial study were depicted.

Intuitively, it appeared that (5.0) would be a good subsystem from which to develop the first mathematical model. The generator or generators could be identified accurately. Signal paths or non-paths in flowchart model form were clearly revealed. Together, these would be the basis for producing mathematical models. The products of (5.0) are tangible in the form of some kind of printed documentation, and to a lesser degree films, filmstrips, slide sets, prerecorded magnetic tapes, charts, etc. No effort was made to determine the dollar value of these expenditures. However, it is believed that $1 billion is a reasonable approximation. Since this is an extremely large sum, any study which would produce better results for the same expenditure, or the same results for considerably less money, would be worthwhile. Many firms and government agencies constitute the group of generators of materials and services because of the variety of occupational fields for which preparation is given in secondary schools. Virtually every industry and every federal agency is represented.

For these reasons, ETC selected (5.0) as the subsystem to be studied as the generator of information inputted into the school. The modeling activity in this study should produce not only a solution but more importantly a
procedure which could be followed to treat additional loops in the same model, and other complex, closed-loop models.

The application of physical science techniques such as systems analysis to a non-physical science problem in social science is quite difficult. The philosophy expressed in the initial proposal and this study, of a cybernetic model consisting of flowchart and mathematical elements, has not been utilized in education systems although several individuals have published papers based on this approach (3). Social systems, of which the education system in this study is a subset, are seen as physical systems and modeled as networks of physical entities which have word descriptors and mathematical equations associated with them (4).

3. Selection of Subsystem (5.8) GOVERNMENT PUBLISH OCCUPATIONAL DATA

The federal government generates and publishes documents each year resulting from agency activities. The yearly output of titles is measured in astronomical units. Most of this material is non-political, i.e. it is technical information of a factual nature without political implications and dealing with subject-matter applicable to thousands of different occupations.

Much government documentation is published by the Government Printing Office and sold by the Superintendent of Documents. However, many titles are distributed by other federal agencies such as the Defense Documentation Center (DDC) and the Clearinghouse for Federal Scientific and Technical Information (CFSTI). The United States Government Organization Manual devotes an appendix to representative publications of departments and agencies of the federal government consisting of fine print filling 25 pages (5). This appendix describes a very small percentage of the total annual output of these documentation generators.

The annual output of titles is mathematically a function of the number of government agencies, budgets of these agencies, permissive legislation by the Congress, diversification of agency activities, internal policy regarding publication and dissemination of significant data, and other elements. This study does not attempt to measure the quantity or effectiveness of such data but assumes that some part of it would be useful to occupational teachers in secondary schools. This assumption is based on interviews conducted in the initial study (2). In terms of that study, which produced a model having 49 loops, the one being reported represents 1/49th of the closed-loop aspect of the model. However, it represents 1/24th of those loops which should be expanded. The evaluations are summarized in 9 categories:

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</table>
As stated in the discussion of the initial study, certain feedback signal paths are more critical than others. It is obvious that 24 closed-loops are sufficiently meritorious to be expanded, in the opinion of the investigators. It is not as obvious that the initial study was not designed to create or invent unique paths.... to synthesize non-existing paths.

It is difficult at this stage to state, for certain, that (5.8) is the best subsystem with which mathematical modeling must begin. There are no known ground rules for selecting the first loop for treatment except that it be simple and uncomplicated relative to the other loops. (5.8) satisfies this criterion. Also, there should be a high probability of success in yielding to quantification. (5.8) satisfies this criterion.

4. Objectives of this Study

a. refine ideographically in flowchart model form, the loop described in Figure 3 (flowchart to be folded v.w.) as (5.8) \(\rightarrow\) (4.6.1.1) \(\rightarrow\) (4.6.2) \(\rightarrow\) (4.6.3) \(\rightarrow\) (4.10) \(\rightarrow\) (4.3.3) \(\rightarrow\) (4.4) \(\rightarrow\) (1.2.1) \(\rightarrow\) (1.1.1) \(\rightarrow\) (1.5.4) \(\rightarrow\) (4.7) \(\rightarrow\) (4.6.1.1).

This loop has this ideogram, derived by analysis:

\[
\begin{array}{c}
1.0 \\
F \\
\rightarrow \\
4.0 \\
\rightarrow \\
\downarrow \\
5.0
\end{array}
\]

b. examine but do not refine alternative feedback signal paths which were not revealed in the initial study; the ideograms of three such alternatives are:

\[
\begin{array}{c}
1.0 \\
F \\
\rightarrow \\
4.0 \\
\rightarrow \\
\downarrow \\
F \\
\rightarrow \\
5.0
\end{array}
\]
c. consider a number of mathematical techniques to quantify the flowchart model in a, above.

d. select the most promising technique and synthesize a set of mathematical expressions which support the position that the model will measure existing occupational teacher performance insofar as updating course content is concerned.

e. publish the results of the study so federal government agencies, as producers and disseminators of data, will learn how to adjust data configuration and current dissemination channels to allow their products to reach and be used by large numbers of occupational teachers and be retransmitted to students.

f. publish the results of the study so other generators of data, represented by functions (5.1), (5.2), (5.3), (5.4), (5.5), (5.6), (5.7) and (5.10) in Figure 3, will understand and accept systems techniques as applied to updating occupational course content in secondary schools.

g. publish the results of the study so the techniques of analysis, synthesis, modeling, and simulacion; as illustrated by this project can be understood and used in general as well as occupational education (6).
B. APPROACH TO PROBLEM

1. Refinement of the Flowchart Model

It is necessary to decompose (5.8) to at least the fourth level of detail so functions and interrelating signal paths are clearly revealed. The sequence of events is:

a. conceptualize a flowchart model of (5.8) based upon the knowledge and experience of the investigators, corresponding to (2.0) of Figure 4.

b. present this subsystem model as an interview-based stimulus to a small number of highly expert individuals in a university setting who respond analytically using their experience; experts have direct contact with secondary school occupational instructors and library documentation practices, corresponding to (1.0) of Figure 4.

c. reconceptualize this subsystem using responses from experts, corresponding to (2.3) of Figure 4.

d. perform a low-fidelity simulation to test and debug the model, corresponding to (3.0) of Figure 4.
2. Conceptualization of the Mathematical Model

a. assume that all content updating is performed in (4.10) of Figure 3, and that this occurs independently of (4.2) which refers essentially to the introduction of completely new or completely revised groups of courses constituting a curriculum.

b. consider the course content as a Markov chain of main facts and teaching points; a course consists of lessons, lessons consist of main facts, main facts consist of teaching points (7).

c. define KEYCEPT as:
   (1) the key word analog of the concept expressed by a main fact (a group of teaching points) in a human-instruction lesson plan.
   (2) consisting of one or more key words which are nouns, adjectives, verbs and/or adverbs.
   (3) an element of a Markov chain.

d. treat KEYCEPT mathematically and overlay the equations on the appropriate subsystems in Figure 3, corresponding to (2.3) of Figure 4.

3. Relationship to Real-Life

It is desirable to synthesize the model by using real rather than contrived data. By definition, a course consists of lessons and the document which contains lesson content and method is the LESSON PLAN. Therefore, obtain a small sampling of lesson plans from occupational teachers; examine these to verify that KEYCEPTS do, in fact, exist and are present in the typical plan.

The KEYCEPT is created in (4.6) of Figure 3 and is recorded on the lesson plan form in (4.10). The lesson plan is used by the instructor in (4.3) and the KEYCEPT is indicative of the information that is transmitted to the student (4.4). The KEYCEPT as such is not transmitted.

The mathematical modeling aspect of the study will be concerned with the (5.8)→(4.6)→(4.10) section of the loop.
C. ANALYSIS

1. Flowchart Model

This section reflects the experience of five experts and the ETC investigators identified in ACKNOWLEDGEMENTS. Reference is made to Figure 3 which resulted from the initial study \(2'\), and to Figure 5 which resulted from steps la, lb and lc, page 11. However, responsibility for the design of this submodel rests exclusively and solely with the principal and associate investigators.

see Page 13a

Figure 5 - Reconceptualized Configuration of \((5.8)\), \((4.0)\), \((5.5)\) and \((7.1)\)
a. Analysis of (5.8)

(5.8) is analyzed as having two functions, (5.8.1) GENERATE MATERIALS, and (5.8.2) DISSEMINATE MATERIALS. Technical materials are created in (5.8.1.1) by federal agencies other than the Department of Defense (DOD), often as byproducts of their routine activities. These may be purchased from the Superintendent of Documents (SOD) in (5.8.2.1), or requested from the generating agency (5.8.2.2).

DOD creates materials (5.8.1.2) not only as byproducts but as endproducts for training and education programs. Additionally, it contracts for the creation of materials from non-government sources (5.8.1.3) and these materials are often available to Educational Resources Information Center (ERIC) organizations (5.8.2.5). It is true to a lesser degree that (5.8.1.1) will contract for the creation of materials by non-government sources as revealed by the signal path from (5.8.1.3) to (5.8.1.1).

DOD produces (5.8.1.2) or has produced for it (5.8.1.3) materials which must by regulation or law be deposited in the Defense Documentation Center (DDC) as described in (5.8.2.4). Occupational teachers ordinarily do not qualify for documents held by DDC. However, certain (5.8.2.4) documents are released to the Clearinghouse for Scientific & Technical Information (CFSTI) shown in (5.8.2.3) and may be obtained as described in Figure 5. (5.8.2.3) also processes documents from (5.8.1.1) through function (5.8.2.2). In addition to receiving documents from (5.8.1.3), ERIC (5.8.2.5) also receives inputs from (5.8.2.2).

Finally, legislators (5.8.2.6) receive materials from (5.8.2.1) and (5.8.2.2) and furnish these whenever practicable.

The (5.8) function as described should account for nearly 100% of government published data which is approved for external consumption.

b. Analysis of (4.0)

(4.0) as depicted in Figure 3 is expanded to the detail in Figure 5. The occupational teacher (4.6) can receive inputs from all functions in (5.8.2) except (5.8.2.4). The school library may receive promotional information from (5.8.2.1) and this might reach (4.6), but the teacher is normally his own search and early-warning sensor. If he is aware of a specific document, he may request it through the school library (4.9.5.1) and the path (4.6)→(4.9.5.1)→(4.9.5.2)→(4.6) is followed.

A more circuitous route involves the acquisition by an appropriate subpart of a state education agency of documentation (7.1) from (5.8.2). This is disseminated in (7.2) and reaches the local school district office (4.9.3.1). It is also possible for (7.1) to disseminate information from (5.8) by inputting (7.2) into (5.5) where a commercially-oriented organization will convert it into instructor's materials which reach the teacher through path (5.5)→(4.9.3.1)→(4.9.3.2)→(4.6). Even if (4.9.3.2) is bypassed, the path is
The school district (4.9.3.1) need not rely solely upon path (7.1) → (7.2) → (5.5) but can input directly form (5.8.2). The Superintendent of Schools and/or the District Director of Vocational Education receive the inputs (4.9.3.1) and either file them or pass them on to the Principal (4.9.3.2) or to the teacher (4.6) perhaps through a department chairman. It is possible for an interested Principal (4.9.3.2) to order materials through his school or district professional library (4.9.5.2) for his teachers. Materials which contribute to updating of occupational course content are not usually ordered by Principals for their own use.

The teacher (4.6) will occasionally use the documentation to assist him in performing the occupational guidance and placement function (4.5) which occurs in (4.3.3). However, this study is concerned mainly with updating content for skills and knowledge rather than for guidance purposes although there is a side effect reinforcing guidance.

It is in function (4.10) that the development of instructional materials is performed by (4.6). The basic device is the lesson plan containing content coupled with the method of instructing the content in detail. The teacher (4.6) uses his inputs to update old content by modifying main facts and teaching points in (4.10.1). If he utilizes his inputs to improve the method of instruction, this is performed in (4.10.2). There is an interaction between (4.10.1) and (4.10.2) when content updating calls for a new method and when new methods force a review of old content. The best instruction and optimized learning occurs when content dictates the method for communicating...rather than the reverse. At the secondary school level, particularly in occupational subjects, the body of knowledge for any particular subject is both well-defined and voluminous. Therefore, content updating decisions to include, delete, or otherwise modify existing content will dictate the method.

2. Mathematical Analysis

The principal objective of the mathematical analysis is to measure existing occupational teacher performance insofar as updating course content is concerned as described in 4d, page 10. This objective requires the measurement of

a. teacher performance
b. old course content
c. updated course content

The first objective of the mathematical analysis is to describe course content in mathematical terms. Then updated course content can be compared readily with the old to determine the amount of change. This actual change can then be compared with the desired change to determine the teacher's performance. The open-loop part of closed-loop (5.8) → (4.6) → (4.10) → (4.3) → (4.4) → (1.2.1) → (1.1.1) → (1.5.4) → (4.7) → (4.6) to be analyzed is:
The first step is to analyze course content in function (4.10.1)

a. Mathematical Representation of Course Content

Consider a course as a sequence of main facts and associated teaching points:

1.1.1 Main Fact, MF(t₁)
1.1.1.1 Teaching Point
1.1.1.2 TP

\[ \vdots \]

1.1.2 MF(t₂)

\[ \text{etc.} \]

where \( MF(t_i) \) designates the \( i \)th main fact occurring at time \( t_i \). The whole course \( C(t) \) is described by the equation:

\[
C(t) = \begin{cases} 
MF(t) & \text{if } t = t_i \\
MF(t_0), 0 \leq t < t_1 & \\
MF(t_1), t_1 \leq t < t_2 & \\
\vdots & \\
MF(t_{n-1}), t_{n-1} \leq t \leq t_n & \\
\frac{n-1}{\sum_{i=0}^{n-1} MF(t_i)[U(t_{i+1}) - U(t_{i})]} & \text{where } U \text{ is the unit step function.}
\end{cases}
\] (1)

Equation (1) defines a course as a sequence of main facts. To compare two courses prepared by two occupational teachers on the same subject, the course equations could be developed in detail and would show whether or not the courses were identical. Because teachers are human and have individual differences, it is quite likely that the courses would not be the same. That is, in general:

\[
C_A(t) \neq C_B(t)
\] (2)

where the course subscripts \( A \) and \( B \) refer to two different teachers. However, in comparing two different versions of a course, the interest is in how much are they alike or, particularly for this study, how up-to-date is the course.

Since, these are statistical concepts of equality, it is necessary to describe main facts in statistical terms. Each main fact appears in the lesson plan as a collection of words. The main fact dealing with any subject-matter is described by certain key words which will be used by most occupational teachers when preparing a lesson plan for the course.

Now, define \( MF(t) \) by the statistics of its key words. Consider these
key word statistics on the key word or w-domain. Then, on the main fact-key word plane, there will be this joint probability density function:

\[ p(w, MF(t)) = p(w|MF(t_0))p(MF(t)) \]  
(3)

The probability will be non-zero for only certain points in the MF-w plane. These points are the key words that represent each specific main fact. This set of key words is called the KEYCEPT for a specific main fact as illustrated in figure 6.

![Figure 6 - KEYCEPT for a Specific Main Fact Defined on MF-w Plane](image)

The KEYCEPT is fixed, thus the conditional probability of key words given a main fact is time-independent:

\[ p(w|MF(t)) = p(w|MF) \]  
(4)

Then, equation (3) may be stated:

\[ p(w, MF(t)) = p(w|MF)p(MF(t)) \]  
(5)

where the only time-dependence is in the last density function. This density function defines the way in which main facts are ordered to synthesize the course. The time-dependence therein is, in fact, the Markov chain statistics for the main fact sequence. In a logically structured course, such as automotive mechanics, the chain would be expected to be of high order while in a less logically structured course the order should be lower.

The chain statistics have meaning also with respect to the organization of a single teacher's course. The more "tightly organized" the course is, the longer will be the chain n. This long chain length reduces the course information content so it is teachable. Therefore, for well-taught courses, i.e. those instructed by good teachers, the chain statistics may be as time-independent as the KEYCEPT statistics.

b. Updated Documentation Representation

Figure 1 describes the flow of updated documentation (5.0) to the occupational teacher (4.0). A more explicit flowchart, Figure 3, identifies the flow as (5.8)\(\rightarrow\)\((4.6.1.1)\rightarrow\)\((4.6.2)\rightarrow\)\((4.6.3)\rightarrow\)\((4.10)\).
In order to determine the performance of occupational teachers (4.6) who incorporate updated documentation into their old course content, (4.10), the documentation and content must be commensurate. In other words, the updated documentation must be represented so course content statistics may be compared with it. One simple way to accomplish this is to select one KEYCEPT for the documentation, then use this as the mean value of the desired updated course content. A slightly more complex representation would be, in addition, to specify acceptable variance limits for the updated documentation.

c. Evaluation of Teacher Performance

The evaluation method established by the representation under discussion is clearly a statistical process. One occupational teacher's performance can be evaluated when he is updating content during several different updating events, or the performance of the teacher population can be evaluated in a specified updating situation. However, meaningful evaluation cannot be conducted of the performance of one teacher in a single updating event. Indeed, the most important and immediate issue is to insure that most course content is up-to-date. This continues to be a statistical problem.

The performance of the system during one updating event can be examined by measuring the variance of performance from the specified mean KEYCEPT. First, count the different KEYCEPTS. Then, arrange this data in histogram form, ordering the KEYCEPTS by the number of times they occur, and placing them alternately on opposite sides of the mean. Next, calculate the variance in numbers of KEYCEPTS. The figure of merit, $M$, for the system is

$$M = E[(K_i - \overline{K})^2]$$

(6)

where $E$ is the expected value of quantity $(K_i - \overline{K})^2$; $K_i$ is $i$th KEYCEPT and $\overline{K}$ is the specified mean KEYCEPT.

d. Evaluation of Updated Content

The effectiveness of the updated content can be similarly evaluated. The specified mean KEYCEPT must reflect the true intentions, $I$, of the generator (5.8) of the original updating material. How well this objective is met may be evaluated by

$$I = |\overline{K} - \sum_i K_i p(K_i)|$$

(7)

If all of the original updating material is used, $I = |\overline{K} - \overline{K}| = 0$ and all of the intentions are implemented.

3. Application to Sample

Two factors must be examined at a practical operating level: 1) obtaining actual lesson plans, and 2) generating KEYCEPTS. This constitutes, in fact, a low-fidelity simulation of the models developed, and corresponds to 1d on page 11, and subsystem 3.0 in Figure 4.
Sample lesson plans were obtained on a random basis, corresponding to (1.2) of Figure 4. Because the study did not include a full-scale simulation, updating materials specifically related to these plans were not sought. Hence, $M(Figure of Merit)$, and $I(True Intention of the Generator)$ cannot be experimentally evaluated as depicted in (3.3) of Figure 4.

a. Acquisition of Sample

Using an ETC mailing list of more than 2,000 individuals who are officials, executives or employees of education or training organizations, the following criteria for selection were utilized:

1. Individual was in a vocational, vocational-technical, or technical public secondary school or school district,
2. School or school district was in the U.S., including territories and possessions,
3. Individual was consulting in, managing, supervising, or instructing automotive mechanics and/or electrical courses.

A letter, Appendix I-1, and a general statement of the study, Appendix I-2, were sent to 86 individuals who satisfied the selection criteria.

b. Data on Obtaining Lesson Plans

Summary of data follows:

| Letters (Appendices I-1, I-2) | 86 |
| Responses, total | 26 |
| Responses, with lesson plans or course outlines, or both | 21 |
| Responses, acknowledgement without lesson plans or course outlines | 5 |

Lesson plans in vocational-technical secondary education tend to be more formalized than in general or academic education. A history of the development of the lesson plan movement, beginning with Herbart in 1806, has revealed this gradual evolution (8). Despite the fact that Charles R. Allen popularized Herbartian philosophies, and contributed to the implementation of the Smith-Hughes Act which resulted in uniformity and near-standardization, lesson plans are still individualized and vary widely in format. This position is supported by examination of the lesson plans submitted.

For the purposes of this study, lesson plans of 6 responding organizations were used.

The instructor writes his lesson plan in a kind of shorthand which communicates to him but not necessarily to someone else who looks at it.
For example, he may write:

Radiator core
  Types
  Construction
  Purpose
  Servicing
  Testing

The 'types,' details of 'construction,' etc., are actually mnemonics or symbolic of teaching points but are not, in fact, teaching points. Here is an example of a clear Main Fact (MF) and Teaching Point (TP) sequence:

Uses of Cooling Systems
  remove excessive heat
  maintain desirable heat
  complement lubricating system
  provide heat for passenger comfort

The investigators considered mnemonics in examining submitted lesson plans.

c. Generation of KEYCEPTS

(1) procedure
  A procedure was designed following these steps
  (a) identify each MF
  (b) identify w for all MF
  (c) generate p(w|MF) in the form of a histogram
  (d) scan and iterate w set for MF until reduction produces w's with highest p(w|MF)

  The main objective was to establish the procedure (subsystem of model) and test it by simulation. A secondary objective was to determine the criterion for the number (n) of w's per KEYCEPT.

(2) simulation #1 (Automotive Spark Plugs)
  Appendix H-3 represents a typical classroom-type lesson plan as submitted to ETC. The investigators identified all MF and TP by marking with hand-lettered MF and TP. This corresponds to 1d on page 11 and to sequence (1.2)→(3.1)→(3.2) in Figure 4.

  The sections, "Instructional Materials" and "Test," were not identified as containing MF and/or TP.

  (a) identify each MF

  MF - objectives
  MF - introduction
  MF - construction
  MF - features
  MF - service procedures
(b) identify w for all MF

MF - objectives
   spark
   plug
   feature

MF - introduction
   spark
   plug

MF - construction
   electrodes
   insulator
   seals
   shell

MF - features
   thread
   reach
   heat range
   gap

MF - service [procedures-deleted]
   removing remove
   cleaning clean
   gapping change to gap
   installing install

(c) generate \( p(w | MF) \) by counting number of times a \( w \) (key word) appears and plotting this as a histogram

MF - objectives
   spark 2
   plug 2
   feature 2

MF - introduction
   spark 3
   plug 2

MF - construction
   electrodes 1
   insulator 1
   seals 1
   shell 1

MF - features
   thread 1
   reach 1
   heat range 1
   gap 1
MF - service

remove 1
clean 1
gap 1
install 1

Service

Features

MF Construction

Introduction

Objective

Figure 7 - KEYCEPTS for Specific MFs Defined on MF-w Plane; Simulation #1.

(d) scan and iterate w set for MF until reduction produces w's with highest p(w|MF).

The histogram in Figure 7 reveals the KEYCEPTS for all MF. This may be compared with the theoretical histogram in Figure 8.

On a tentative basis, the criterion for w/K (number of words per KEYCEPT) is: a specific w must appear at least twice in some MF.

(3) simulation #2 (Cooling System)
Appendix H-4 represents a typical classroom-type lesson plan as submitted to ETC. As before, MF and TP were identified by hand-lettering. This simulation corresponds to ld on page 11 and to sequence (1.2)→(3.1)→(3.2) in Figure 4. All sections contained MF and/or TP.
(a) identify each MF

- Introduction
- Types
- Uses
- Components/Liquid
- Components/Air
- Temperature
- Heat Sources
- Heat Dissipation
- Enemies
- Pumps
- Thermostat
- Core
- Fan
- Restrictions
- Pressure Systems
- Pressure Caps
- Antifreeze
- Servicing
- Air Cooled
- Summary

(b) identify w for all MF

[same procedure as in simulation #1]

(c) generate p(w|MF) by counting number of times w appears and plotting this as a histogram, Figure 8.

In the process of developing Figure 8, it was discovered that engine and lubricate were of high-frequency and had been inadvertently omitted in the first pass through (b) above. ETC believes this does not call for creating and adding an additional step to the procedure designed on page 20.

(d) scan and iterate w set for MF until reduction produces w's with highest p(w|MF)

The histogram in Figure 8 reveals that five w's, marked x, have only one representation in any one MF. If the w-domain for defining KEYCEPT is restricted to w's which occur more than once in some MF, then those marked x are to be discarded. This does not create any ambiguity in relating an MF with its KEYCEPT.
<table>
<thead>
<tr>
<th>Topic</th>
<th>Elements</th>
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<tbody>
<tr>
<td>Introduction</td>
<td>1 1 2 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>Types</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>Uses</td>
<td>1 1 1 1 1 1</td>
</tr>
<tr>
<td>Components/Liq</td>
<td>2 1 1 1 1 1 1 1 1 1 1 1 1 1 2</td>
</tr>
<tr>
<td>Components/Air</td>
<td>1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>Temperature</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1 2</td>
</tr>
<tr>
<td>Heat Sources</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>Heat Dissipation</td>
<td>2 4 2 1 6 2 1 4 1 2</td>
</tr>
<tr>
<td>Enemies</td>
<td>1 2 1 1 1 2 1 3</td>
</tr>
<tr>
<td>Pumps</td>
<td>1 1 1 3</td>
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<td>Thermostat</td>
<td>1 1 1 1 1</td>
</tr>
<tr>
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</tr>
<tr>
<td>Fan</td>
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<tr>
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<td>Pressure Caps</td>
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<tr>
<td>Antifreeze</td>
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<td>Servicing</td>
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<td>Air Cooled</td>
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</tr>
<tr>
<td>Summary</td>
<td>1 1 1 1 1 1</td>
</tr>
</tbody>
</table>

Figure 8 - KEYS for Specific MFs Defined on MF-w Plane; Simulation #2
D. Summary of Analysis

1. Origin and Flow of Government-Published Information

The study has examined the origin and flow of government-published information initially identified in Figure 2 and reconceptualized in Figure 5.

The flow of information is (5.8)→(4.6)→(4.10,1) as shown on page 16 and is the open-loop part of the complete close-loop (5.8)→(4.6)→(4.10)→(4.3)→(4.4)→(1.2,1)→(1.1,1)→(1.5,4)→(4.7)→(4.6)

2. Quantification

The study has produced a mathematical representation consisting of models on pages 16-18. This corresponds to subsystem 2.0 in Figure 4. Simulation was performed twice to be certain the models were of high-fidelity. Only two samples were used, thus the simulation was itself of low-fidelity. This corresponds to subsystem 3.0 in Figure 4.
E. Discussion of Results

1. Validity of Model

The histograms in Figures 7 and 8, based solely upon real-life human-instructor lesson plan content, compare well with the concept expressed in Figure 6.

In the simulation effort, the lesson plan for "Automotive Spark Plugs" was only at the 2nd level of detail and was highly mnemonic, i.e. the instructor relied mainly upon his own memory, or used other documentation, in his lesson. It was in his shorthand which communicated to him. This is supported by the "test" part which uses such terms as: fuel-air mixture; high-speed conditions; voltage requirements; fluffy, black, dry deposits; fouling; polarity; blistered, burned, badly eroded electrodes; etc. For this reason, simulation #1 in Figure 7 revealed only low w-counts for \( p(w|MF) \).

However, the lesson plan for "The Cooling System" reached the 4th level of detail and was quite specific and complete in detailing various elements at all levels. This is shown in simulation #2, Figure 8. The \( p(w|MF) \) in this lesson is represented by higher w-counts, accompanied by a low mnemonic level.

2. Synthesis of Updating Subsystems

What appears to be missing from the network is a return path from the real-life situation (1.0) to the educational institution (4.0) and/or to generator (5.0). This return path would close the loop, thereby producing one of the ideograms on page 9.

However, feedback signal paths from (1.0) to (4.0) alone do not produce changes in, or control, the output of (5.0). If the design objective is to update instructional content, through the use of technical government-published information, then (5.0) must output to (4.0) and (4.0) must have a return feedback path to (5.0). Of course, it is possible for this return to pass through (1.0) and then return to (5.0).

After examining the real-life lesson plans and the mathematical modelling and simulation, it has become clear that a feedback return through (4.0) would take too long and that an additional path from (4.0) to (5.0) would be of great value.

This path is seen in Figure 9 as (4.6) → (4.1.0.1) → (5.8.3) → (5.8.1.4) → (5.8.2.1) → (4.6). A close alternative is (4.6) → (4.9.3.1) → (5.8.2.1) → (4.9.5.1) → (4.6) → (4.1.0.1) → (5.8.3) → (5.8.1.4) → (5.8.2.1) → (4.9.5.1) → (4.6). They differ mainly in the specific manner of procurement from the Superintendent of Documents.
When an agency creates data (5.8.1.1) it is sent to the Superintendent of Documents where it is disseminated to many individuals only some of whom may be occupational teachers (4.6). Let us create a function (5.8.1.4) which analyzes this data in the occupational frame of reference and then translates the most essential elements into a special format. This format has not been formularized but it has as its attributes:

a. high *figure of merit* (low or zero M)
b. high *frequency* (f) capability
c. low or zero variance from *intention of the generator* (I)
In other words, the occupational teacher continuously receives updating data in a format requiring virtually no alteration and which is integrated into his lesson plan and taught as it was intended to be comprehended by the author or translator.

The flow is (5.8.1.1)→(5.8.1.4)→(5.8.2.1)→(4.6)→(4.1.0.1)→(4.3) but feedback outputs (4.1.0.1) to (5.8.3) and returns to (5.8.1.4). The (4.1.0.1) function is sampled and enters into the comparator function (5.8.3) where it is mapped onto criteria. Communication malfunctions are detected and analyzed in (5.8.3) and these enter (5.8.1.4) and control the output to (5.8.2.1).

Without the feedback path (4.1.0.1)→(5.8.3)→(5.8.1.4), the output of (4.1.0.1) is under control of long time delay signals from various subsystems described elsewhere and depicted in Figure 3 (2). In terms of this study, and ignoring any other feedback signals, part of the model interrelating (5.8) and (4.10) is open-loop. The ideograms on page 9 are representative of this relationship.

With the feedback path (4.1.0.1)→(5.8.3)→(5.8.1.4), the output of (4.1.0.1) is under control of both short time and long time delay signals as described in Figure 9. The model in Figure 9 closely represents the lower ideogram on page 9. Again, in terms of this study and ignoring any other feedback signals, part of the model interrelating (5.8) and (4.10) is closed-loop.

The design of functions (5.8.3) and (5.8.1.4) in the process of synthesizing the updating subsystems and relationships is of great importance. In essence, the feedback can only be used to control the output of (5.8.1.4) if the products reach the occupational teacher and are used to update his lessons (4.1.0.1). There are many who prefer a diminishing of federal government relationships with operating level personnel such as secondary school teachers particularly when the input from Washington, D.C., is curriculum content. At first glance, the path (4.1.0.1)→(5.8.3)→(5.8.1.4) merely assists the government bureau in modifying (5.8.1.1) output so it can be better assimilated by (4.6). However, the path is closed-loop and this means the occupational teacher must use the government material in his lesson plans if the output of (4.1.0.1) is to be sampled and returned to (5.8.1.4) via ((5.8.3). In this sense, the design may appear to impose federal control of lesson plan content in public secondary schools at the local operating level...a clear violation of states rights and home rule.

However, the crucial issue is not one of federal control but of system equilibrium. The real-life environment which provides employment can survive and grow only if manpower competence keeps pace with technological growth. The open-loop design of nearly all educational configurations, which by definition is insensitive to the real-life environment, is unstable and in a state of disequilibrium. Managers from business, industry, and government organizations have long criticized secondary schools. Now, these managers are joined by students and parents who feel that high school graduates are not properly prepared for the real world of work. And, as might be expected, there are many teachers and school administrators who agree.
When systems are simple, the number of functions and their interrelationships is small. When systems grow in size and begin to relate to other growing systems, the new whole being formed is of greater complexity than the arithmetic sum of the individual complexities. Complexity is just a function of set size and the number of interrelationships. Simple systems tend to be open-loop. Complex systems which are not closed-loop tend to become unstable. All systems have resonant or critical frequencies at which inherent natural vibrations are maximum. This is characterized by the release of energy in the form of oscillations. A system is in equilibrium when no spontaneous oscillations occur in it. Systems in equilibrium are said to be stable. Therefore, a system which is designed in a closed-loop configuration can have an operating tolerance zone within which it will remain in equilibrium.

If a rotating propeller in a physical system is not properly feathered and speed-governed, it can build up oscillations and disintegrate. The same would be true in a social system of which the educational system is a subset. Open-loop or poorly designed closed-loop education systems can disintegrate if they grow in complexity beyond their operating tolerances.

In this study, disequilibrium caused by open-loop design has been reduced through the synthesis of a feedback signal path together with several new functions.

Very few government organizations have any permanently organized feedback signal path from the users of their information disseminated by SOD (5.8.2.1). The U.S. Department of Labor recently issued questionnaires for a Manpower Report Use Survey, which included school or vocational training unit in the question dealing with "kind of organization in which you work" (9). It also listed among the "uses,"

- teaching - student text book
- teaching - student reading reference
- teaching - preparation of lectures

Thus, some awareness exists in the Department of Labor that teachers do utilize government-published information but this is a relatively crude measurement not considered to be typical of the (5.8.3) and (5.8.1.4) functions in Figure 9. In (5.8.1.4) the content of a technical document is translated into a format of immediate usefulness to an occupational teacher. Feedback through (5.8.3) modifies either the format or the content or both.
F. Conclusions, Implications and Recommendations

Flowchart and mathematical models have been synthesized and tested using low-fidelity simulation, corresponding to (1.0), (2.0) and (3.0) of Figure 4. These models are valid for the purposes of this study.

It has been demonstrated that quantitative techniques can be developed and applied to an educational system such as a comprehensive vocational-technical secondary school.

The flowchart model described in Figure 3 dealing with (1.0), (4.0) and (5.0) was created in the initial study. It has this ideogram, derived by analysis:

```
|    4.0    |
|   F     |
|    1.0    |
```

It is concluded in this study that the following ideogram obtained through synthesis would be superior:

```
|    4.0    |
|   F     |
|    1.0    |
```

The study focused upon (4.0), (5.0) interrelationships. Figure 5 describes functions to the fourth level of detail but that particular section of the model is open-loop. To obtain system equilibrium, it was necessary to synthesize the feedback signal path shown in Figure 9...a closed-loop in which part of the output of (4.10.1) is sampled and fed back through (5.8.3) to control...
the output of (5.8.1.4).

Mathematical techniques were used to identify KEYCEPTS created in (4.10.1), and to examine the performance of the system.

There are several different directions which may be pursued as a result of this study.

1. at the microlevel, a pilot development project might be established to follow (5.8.1.1)→(5.8.1.4)→(5.8.2.1)→(4.6)→(4.10.1)→(5.8.3)→(5.8.1.4). This would be within a single government agency. The major effort would be to examine data generated (5.8.1.1), (5.8.1.2) or (5.8.1.3) and translate it into a suitable format. The design effort would be to establish the closed-loop path with low entropy.

2. at the macrolevel, continued examination of the model initially developed under contract OEC-4-7-061544-1601 using the techniques formulated in this study.

More significant, however, are the implications for educators and training specialists dealing with systems:

1. open-loop systems in education predominate

2. government-furnished information currently flows in an open-loop to occupational teachers in secondary schools

3. government-furnished information is usually not in a form easily used by occupational teachers

4. lesson plans produced by occupational teachers vary widely in level of detail

5. lesson plans can be analyzed into main facts and teaching points

6. KEYCEPTS can be identified in lesson plans using specialized techniques; while manual methods were utilized in this study, optical character recognition and computing techniques can easily produce the quantitative results

7. updating content created from government-published information can be analyzed into KEYCEPTS

8. if government-furnished information is placed into a closed-loop system, updating KEYCEPTS will enter an occupational teacher's lesson plan, obsolete KEYCEPTS will be displaced by updating KEYCEPTS, and that part of teacher performance which deals with the updatedness of subject-matter content can be measured.

9. the KEYCEPT conceptualization has been applied to occupational subject-matter which is, by examination, highly factual; there is every reason to believe that it can also be applied to certain academic or general education subject-matter
10. the modeling technique in this study has been developed for subsystem (5.8); there is every reason to believe that it can also be applied to other parts of the PRODUCE RESOURCE MATERIALS & SERVICES, such as:

- hardware manufacturing (5.1)
- books for teachers and students (5.5)(5.6)
- manuals and catalogs for teachers (5.2)
- trade papers for teachers (5.7)

and also to other subsystems in Figure 3.
# AUTOMOTIVE SPARK PLUGS

## Lesson Plan

**OBJECTIVES:**

1. To list the features of a spark plug and the significance of each feature.
2. Given a sectional view of a spark plug, to identify the components.

## INSTRUCTIONAL MATERIALS:

1. Overhead projector, screen, and transparencies
2. Live engine
3. Spark plug cleaner
4. Blow gun
5. Feeler gage, wire type
6. Spark plug socket
7. Ratchet
8. Gap tool
9. Solvent, non-flammable
10. Vise

## INTRODUCTION:

The purpose of a spark plug is to create a spark within the combustion chamber. The spark plug is a durable and reliable part of the ignition system; however, the voltage and compression conditions under which it works call for periodic service.

## PRESENTATION:

1. **Construction**
   - a. Electrodes
   - b. Insulator
   - c. Seals
   - d. Shell

2. **Features**
   - a. Thread

| Transparency | Transparency |
Appendix H-1 Letter Inviting Submission of Lesson Plans

We are presently engaged in a study to develop models dealing with occupational teaching as described in the attachment. I am writing because of your familiarity with Dr. Leonard C. Silvern's previous work in this field.

May we invite your cooperation for our research? I wish to obtain a copy of one lesson plan now used in automotive mechanics and a copy of one used in electrical courses. Photocopies of actual plans including those handwritten are desired.

Lesson plan copies and questions arising from this request should be sent to my attention. An acknowledgement will appear in the final report. We appreciate your cooperation in this important effort for the U.S. Office of Education.

Cordially,

EDUCATION and TRAINING CONSULTANTS Co.

Christine Cullen
Research Assistant
Educational Systems Division
LOS ANGELES -- The U.S. Office of Education has awarded ETC a contract to develop mathematical models for occupations, it was announced by Dr. Leonard C. Silvern, president.

The study is to produce quantitative models which describe and measure the utilization of government-published occupational data by vocational and technical teachers in high schools. The Federal government creates and disseminates vast amounts of technical information in the form of handbooks, manuals, guides, texts, brochures and periodicals. Some of these are of value to classroom, laboratory and shop teachers to update their lessons and offer information which keeps pace with changes in the occupations.

Dr. Silvern and Carl N. Brooks are conducting the research assisted by Christine Cullen of ETC's Educational Systems Division. They view the occupational teacher as an information processor, and agencies of the Federal government as generators and distributors of information. The student is a receptor and applies what he has learned to the real-life environment when he is employed after graduation.

F. Water Jacket—passages & distributing tubes
G. Coolant
H. Temperatures gauge
  1. Dash unit
  2. Engine unit

IV. Components of an air cooled system
A. Fan or blower
B. Baffles or ducts
C. Cylinder fins or head fins

V. General Temperature Requirements
A. About 30°F or slightly below boiling

VI. Heat Sources
A. Engine friction
B. Condensation heat

VII. Heat Dissipation
A. 1/3 of heat energy from fuel is converted to power
B. 1/3 goes out of exhaust— unused— wasted
C. 1/3 handled by cooling system

Heat removed by a normal cooling system of an average automobile or truck at normal speed would keep a six room house warm at 70°F. This system requires several thousand gallons of water circulating in the cooling system to absorb heat and carry it to the radiator for disposal. Heat generated by the burning mixture in the engine must be transferred from the iron or aluminum cylinder to the water jacket. This heat is dissipated to the air surrounding the cylinder block and other heat is carried by the coolant to the radiator and then dissipated to the air.

VIII. Enemies of cooling systems (Liquid)
A. Rust—caused by water, oxygen, and air
B. Lime—from water supply or may be formed when water is repeatedly heated and cooled.
C. Oil or grease—often blinds lime and rust to iron, causing hot spots along with stoppage or corrosion in passages and distributing tubes.
<table>
<thead>
<tr>
<th>Service procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Removing</td>
</tr>
<tr>
<td>b. Cleaning</td>
</tr>
<tr>
<td>c. Gapping</td>
</tr>
<tr>
<td>d. Installing</td>
</tr>
</tbody>
</table>

**APPLICATION:**

Job sheet no. ____

**TEST**

Complete the following statements by filling in the appropriate word or words in the space provided.

1. The spark plug ignites the fuel-air mixture at or near the top of the _____ stroke.
2. The insulating material on almost all spark plugs is __________.
3. A spark plug with a _______ heat range is manufactured for use in an engine that normally runs under high-speed, heavy-load conditions.
4. A 0.020 inch increase in plug gap may increase voltage requirements as much as ________.
5. Spark plugs need service more often under ________ driving conditions.
6. Fluffy, black, dry deposits on a spark plug are evidence of ________ fouling.
7. Spark plug gaps should always be checked with a ________ feeler gage.
8. The center electrode of a spark plug should have ________ polarity.
9. A blistered or burned insulator and badly eroded electrodes indicate ________ plugs.
INTRODUCTION:

The purpose of the cooling system, a gasoline or diesel engine, is to prevent temperatures of cylinders, pistons, valves, and other engine parts from rising high enough to destroy them or to destroy the oil which lubricates them.

MF I. Types of cooling systems.
   A. Liquid - Direct
   B. Air - Indirect

MF II. Uses of cooling systems.
   A. Remove excessive heat
   B. Maintain desirable heat
   C. Complement lubricating system
   D. Provide heat for passengers comfort

MF III. Components of a liquid cooling system:
   A. Radiator Core
   B. Hoses & or pipes
   C. Water pump
   D. Fan blades & pulley
   E. Thermostat
IV. Components of an air cooled system

A. Fan or blower
B. Ducts or ducts
C. Cylinder fins or head fins

V. General Temperature Requirements

A. About 200°F slightly below boiling

VI. Heat Sources

A. Engine friction
B. Conduction heat

VII. Heat Dissipation

A. 1/3 of heat energy from fuel is converted to power
B. 1/3 goes out of exhaust - unused - wasted
C. 1/3 handled by cooling system

Heat removed by a normal cooling system of an average automobile or truck at normal speed would keep a six room house warm at 70°F winter. The system requires several thousand gallons of water circulating in the cooling system to absorb heat and carry it to the radiator for disposal. Heat generated by the burning mixture in the engine may be transferred from the iron or aluminum cylinder to the water jacket. Some heat is dissipated to air surrounding the cylinder block or other heat is carried by the coolant to the radiator and then dissipated to the air.

VIII. Enemies of cooling systems: (Liquid)

A. Rust - combination of water, oxygen, and air
B. Lime - from water supply or may be formed when water is repeatedly heated and cooled
C. Oil or grease - often builds lime and rust to iron, causing hot spots along with stoppage or corrosion in passages and distributing tubes
Water pump,

A. Components of average pump

1. Impeller

2. Impeller vane -- may be straight, but in most cases they are curved to accelerate outflow of water.

3. Shaft

4. Seals

5. Electric control

6. Thermostat

B. Operation

1. Housing

2. Impeller

3. Seal

4. Bearing

5. Testing

C. Purpose in the system

1. General types

2. Special types

D. Location
XVI. Pressure Systems.

A. Purpose
Provides a wider margin between a desirable operating temperature and the boiling point of coolant being used.

B. Principles Involved
1. Water boils at 212°F at Sea level
2. It boils at 194°F at 10,000 ft.
3. We can raise the boiling point by putting it under pressure.
4. Each pound of pressure added will increase the boiling point by about 3°F
5. By adding 7 lbs. of pressure, water will boil at 200°F at 10,000 feet or at 233°F at sea level.

XVII. Antifreeze Solutions

An alcohol antifreeze solution for protection to 20°F below "O" boils at about 180°F or below the efficient operating temperature of the engine. Add 7 lbs. of pressure, boiling point then up to about 200°F.

XVI. Pressure Caps

1. Blow-off valve consists of a valve held against a valve seat by a calibrated spring. The spring holds the valve closed so that pressure will be produced in the system. If the pressure increases above the pressure determined by the calibration of the pressure spring, the valve raises from its seat relieving the pressure.

2. The Vacuum valve is designed to prevent the formation of a vacuum in the cooling system. When the engine is shut off and begins to cool, if a vacuum forms, atmospheric pressure from the outside causes the small vacuum valve to open admitting air into the radiator. Without a vacuum valve, the pressure within the radiator might drop so low that the atmospheric pressure would collapse it.

XVII. Antifreeze Solutions

A. Types
1. Alcohol - (alcohol base)
   - Non-permanent type - evaporates below the boiling point of water, requires constant attention if desired protection is maintained.
2. Ethylene alcohol - permanent type.
   - Remains liquid at the boiling point of water - little or no loss due to evaporation.

Note: Water expands 9% in volume when it freezes, therefore...
VM. Servicing the cooling system.

1. System must be clean
2. System must be clean- protected by rust inhibitor
3. Hose in good condition and all connections tight
4. Drive belt properly adjusted
5. Protected to a desired point above or below freezing.
6. Must be flushed throughly if it becomes contaminated with rust, oil, scale, etc.

XIX. Air Cooled System

1. Examples
   1. Corvair gasoline
   2. V. W. gasoline
   3. Deitz Diesel
   4. 2 cycle gasoline

2. Requirements
   1. Requires constant circulation of air (copious)
   2. Abundant volume
   3. Area to be cooled surrounded by sheet metal
   4. Cooling fins to assist (air directed to them)
   5. Driver fan by belt to crank shaft
   6. Controlled by thermostat
   7. Mechanically linked to blower ring or damper
   8. Adequate cooling depends on engine speed
   9. Over heating occurs if idled too long
   10.olsier because of lack of water jackets and additional clearance in operating parts

SUMMARY:

All engines are designed to operate in a definite temperature range which will insure correct clearances between parts, promote vaporization of fuel, keep the oil at its best viscosity and prevent the condensation of harmful vapors. In order for the cooling system to do these jobs well preventive maintenance and seasonal attention is a must.

END

9-21-70