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ABSTRACT

STITE (Scientific and Technical Information Transfer for Education) is basically a system to interface between science information and the science learner. As such STITE acts as a link between STIC (Science and Technology Information Centers) and LIS (Learning Information Systems). In this third progress report it is concluded from a questionnaire sent to science educators that they are among the heaviest users of science literature but would prefer an easier and faster method of access. STITE interface system is designed for effective use of information stores. The modules of STITE are manipulable units of information relevant to specific needs of educators. The question of relating and structuring the modules of the interface system by types of requests is described using tree graphs. In the appendixes are some of the project's letters, the questionnaire, and lists of centers receiving utilization inquiry. (See also IR 001 047 and IR 001 048.) (WH)

ED 095869

RESEARCH REPORT

SCIENTIFIC AND TECHNICAL INFORMATION TRANSFER FOR EDUCATION

(STITE)

REPORT NO. 3

Pranas Zunde
Project Director

June, 1974

GEORGIA INSTITUTE OF TECHNOLOGY

ATLANTA, GEORGIA

IR 001 049

SCIENTIFIC AND TECHNICAL INFORMATION TRANSFER FOR EDUCATION

(STITE)

Third progress report on research performed at the School of Information and Computer Science, Georgia Institute of Technology, Atlanta, Georgia, under National Science Foundation Grant No. GN-36114.

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The work described in this report consists of partial results of an in-depth study of information acquisition practices and needs of science educators and a tentative conceptual outline of an interactive STITE interface system for the enhancement of the use by educators of existing science and technical information systems. In both cases, the investigations represent the initial phases of the final areas of concentration of this research effort. Participation of Dr. T. C. Ting, Associate Professor of Information and Computer Science, Dr. Albert N. Baure, Assistant Professor of Information and Computer Science, and Mrs. Dorothy S. Hughes, Research Analyst and Librarian, in this phase of the study is gratefully acknowledged. They appear as authors or co-authors of the portion of this report to which they made major contributions.

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THE INFORMATION ACQUISITION PRACTICES AND NEEDS OF SCIENCE EDUCATORS

PART ONE

THE INFORMATION ACQUISITION PRACTICES AND NEEDS OF SCIENCE EDUCATORS

Albert Badre, Dorothy S. Hughes, and T. C. Ting

I. INTRODUCTION

The ultimate goal of the STITE project is to implement an experimental mechanism for the purpose of transferring scientific and technical information from its present repositories into a system that will enhance the use of scientific and technical information centers by providing that information in a form and manner that correspond more precisely to the exact needs of the science educator community.

One prerequisite for the achievement of this goal is some understanding about the actual information needs of science educators and the factors, external to the information itself, that influence the educator in the acquisition and use of information. According to Bourne (13), the first step in the design of an effective information system consists of the definition of the problem and the determination of user requirements. The actual design and evaluation then follow. An effective system must be constructed in terms of realistic conclusions about the kinds of information that educators require for their particular tasks and the conditions that influence its acquisition and use.

STITE is following two lines of inquiry to answer these questions. A literature analysis investigates previous studies on users of information and attempts to extrapolate conclusions they make about the needs of the particular group of information users in which STITE is interested, the science educators.

Secondly, a questionnaire sent to science educators at various colleges and universities over the country solicits answers from science educators themselves about their use of existing information centers, the types of information they use, for what purposes they use it, and the features that they feel might increase their use of information sources. The data received in response to this questionnaire and the conclusions of the literature survey will provide the basis for design features of the STITE system.

II. THE LITERATURE ON USERS AND THEIR NEEDS

1. Introduction - A user study, or user survey, is an investigation into the ways in which a particular information center or library is utilized or into the utilization of the information sources of a particular subject area, such as chemistry or physics. Brittain (14), agrees that user studies are of these two types. First, there are those investigations that are limited to a particular center or establishment and are concerned with conclusions relative only to that particular center. Secondly, there are those studies that examine the information requirements of a particular discipline.

Coover (16), describes the methodology of user studies as including interviews, questionnaires, critical-incident studies, reference records, or a combination of some of these methods, and inquiry may be made into who is using information resources, what types of materials are being used, and for what purposes the information is obtained.

The information explosion has been accompanied by concurrent studies in the use of that information, and there is no lack of studies on users and their needs.

A study on the use of scientific literature for the Royal Society's Scientific Information Conference in 1948 (9), is frequently cited as the "classic" user study; it is, along with Urquhart (36), one of the earliest such studies.

Since then, as Brittain (14), states, "the growth of emperical studies in this area can be represented by an exponential curve." Two of the best have been those done by Menzel (28), and Paisley (31). An indication of the number and scope of these investigations is shown by the following list of bibliographies and reviews of user studies:

Bibliographies and Reviews of User Studies - (Note: The notation, such a ED068101 or ED047736, which follows some entries in this bibliography refers to the number assigned that report by the Educational Resources Information Center (ERIC).)

Allen, Thomas J. "Information Needs and Uses." In Cuadra, Carlos, ed., Annual Review of Information Science and Technology. Chicago, Encyclopedia Brittanica, 1969. Vol. 4, p. 1-29.

Bates, Marcia J. User Studies: A Review for Librarians and Information Scientists. 1971. 60 pp. ED047738.

Brittain, J. M. Information and Its Users: A Review With Special Reference to the Social Sciences. New York, John Wiley, 1971. 208 pp.

Carter, Launar F., et al., National Document Handling Systems for Science and Technology. New York, John Wiley, 1967. 344 pp.

Coover, Robert W. "User Needs and Their Effect On Information Center Administration." Special Libraries, 60:446-456 (September, 1969).

Crane, Diana. "Information Needs and Uses." In Cuadra, Carlos, ed., Annual Review of Information Science and Technology. Chicago, Encyclopedia Brittanica, 1971. Vol. 6, p. 3-39.

Davis, Richard A., and Catherine A. Bailey. Bibliography of Use Studies. Philadelphia, Pa., Drexel Institute of Technology, Graduate School of Library Science, 1964. 98 pp.

Herner, S., & M. Herner. "Information Needs and Uses in Science and Technology." In Cuadra, Carlos, ed., Annual Review of Information Science and Technology. Chicago, Encyclopedia Brittanica, 1967. Vol. 2, p. 1-34.

Lin, N., and W. D. Garvey. "Information Needs and Uses." In Cuadra, Carlos, ed., Annual Review of Information Science and Technology. Chicago, Encyclopedia Brittanica, 1972. Vol. 7, p. 5-37.

Lipetz, Ben-Ami, "Information Needs and Uses." In Cuadra, Carlos, ed., Annual Review of Information Science and Technology. Chicago, Encyclopedia Brittanica, 1970. Vol. 5, p. 3-32.

Menzel, H. "Information Needs and Uses in Science and Technology." In Cuadra, Carlos, ed., Annual Review of Information Science and Technology. Chicago, Encyclopedia Brittanica, 1966. Vol. 1, p. 41-69.

Paisley, W. J. "Information Needs and Uses." In Cuadra, Carlos, ed., Annual Review of Information Science and Technology. Chicago, Encyclopedia Brittanica, 1968. Vol. 3, p. 1-30.

Slater, Margaret. Technical Libraries: Users and Their Demands. London, Aslib, 1964. 126 pp.

Slater, Margaret, and Pamela Fisher. Use Made of Technical Libraries. London, Aslib, 1969. 86 pp.

Wood, D. N. "User Studies; A Review of the Literature from 1966 to 1970." Aslib Proceedings, 23:11-23 (1971).

In addition, each issue of Science Information Abstracts has a section called "User Studies and User Surveys" which abstracts investigations into the users of information centers and libraries, and Library Literature and Library and Information Science Abstracts also contain headings on user surveys.

Brittain (14), as well as Coover (16), Hanson (24), and others, questions the value of much data obtained in user studies for the purpose of formulating definitions of needs. Hanson (24), points out that because of the difficulty in exploring real needs, most studies have in fact been of users' actions and their expressed demands. While these observable actions, such as where and how often information is sought, do partially reflect some needs, such a measurement does not take into account the more subtle assessments of needs when the user perceives limitations within his information environment or if he remains unaware of the existence of potentially helpful information sources. For instance, in relation to the

STITE project and its fulfillment of needs, will a science educator specifically indicate his desire or need for a service or a system if he does not know of it or of its possibilities?

Nevertheless, granting the inherent limitations of most user surveys in measuring information needs, their partial assessments can usually be the basis for some generalization about trends and directions. There exists only a small number of studies specifically on the needs of science educators, but some investigations into the information needs of scientists include findings in the area of science education, and there are also a few studies on information use in education that have significance for the particular field of science education. Some of these studies will be examined in the light of their implications and implicit findings for the goals of STITE.

2. Some Relevant Studies - In an early (1957) study, "Use of Information in Scandinavian Research and Development", Törnudd (35), investigated the requirements for scientific and technical information of academic, research and industrial scientists in Denmark and Finland. The "academic" section comprised scientists and engineers working at universities and institutes of technology in which their time was divided between research and teaching while the other two groups were involved almost entirely with research. It was found that teachers in academic institutions were among the heaviest users of literature. Even in 1957 when the volume of literature was less than it is today, this group spent from two to ten man-hours per week using literature, and they indicated that they had less difficulty keeping abreast with current developments in their field than did their counterparts in research and industry.

Menzel (29), studied the information-exchanging behavior of a group of scientists on the teaching faculty of a prominent American university in order to define problems, categories, and procedures for a more intensive study. Among this group, information was sought primarily for the purpose of answering a particular question or problem with specific data or facts and for keeping up to date. Formal methods of acquisition were probably less important than informal methods, such as personal communication with colleagues. This reliance on informal channels points up some inefficiencies of formal channels, such as time lag and overloads of information, and suggests that ways must be found to incorporate the informal avenues of communication into them.

Bartkus (5), prefaced his descriptive article on the major sources of information for engineering educators with a list of their needs;

> "The engineering educator is concerned with the information needs of:
>
> 1. Himself, to keep up to date technically.
> 2. His classroom students, to develop their use of information sources, both in solution of class problems and actual problems after graduation.
> 3. His research students, to assure coverage of previous work.
> 4. His associates, on a consulting project or in research.
> 5. His publications, to assure that he contributes to knowledge."

The American Psychological Association (2), has reported on its investigation into the information requirements of university teachers of psychology in Report Number 17, "The Use of Scientific Information In the Undergraduate Teaching of Psychology," of its Project on Scientific Information Exchange in Psychology. Conducted by a questionnaire to psychology faculty members of 246 American institutions of higher learning, this study revealed that teaching is a very time-consuming activity and a very information-demanding one. The need to up-date lecture material was given as the most frequent reason for seeking information, and in addition to current journals used for this purpose, two-thirds of the respondents indicated that they maintain personal files of reprints and convention papers, to assist them in keeping up-to-date. For lecture preparation, text books were also frequently consulted.

The primary problem of information seeking among psychology teachers seemed to be the lack of sufficient time to locate and assimilate relevant materials. The report concluded that, while this group of science educators uses a large number of formal and informal sources of information in their work and is particularly eager to use current and up-to-date materials, they encountered a lack of materials that are selected and processed in such a way as to save time for themselves and for their students.

In the social sciences, Brittain (14), cited a report by Winn on a group discussion among college of education lecturers that was a part of a study of users of Sociology of Education Abstracts. The greatest information problem felt by this group was physical access to books and journals. However, these lecturers felt that the solution to this problem lay, not in expansion of local book holdings, but rather in an information service that would provide easy access to and some evaluation of a limited range of materials. Retrospective searches presented another problem for them, and a retrieval system, keeping in mind this group's feeling that abstracts are more valuable than titles, was suggested as a solution.

A more comprehensive study of the information needs of social scientists, known as INFROSS (Information Requirements of Social Scientists), was conducted by Bath University in 1968 (7). Defining education as a social science, this investigation included a report on data secured through group interviews with college of education lecturers. Since the sample was small, the results were intended more to provoke further study than to be representative, but the conclusions made about information requirements and activities of educators bear some significance for the special group, science educators, in which STITE is interested.

When work involved teaching only, the need was usually for specific pieces of information, such as a fact, or for general information, such as new developments in remedial reading. Comprehensive coverage was not usually required. Reading done by this group seemed to be haphazard and largely dependent on whatever happened to be available; there seemed to be little effort to keep informed on new developments in their fields and little awareness of available literature and materials.

One aspect of information mentioned by most of the interviewees in this group was the importance of its stimulus value, both for lecturers and for students. However, this characteristic presents peculiar, if not impossible, requirements for an information system because of the difficulty in defining and describing what "stimulates".

Because of this desire to keep informed of developments but with little time and information resources to do so, this group would seem to find review literature most useful, and the interviewee frequently mentioned this type of article. A well developed review literature, with adequate access to it, might serve this group better than bibliographic tools.

Some bibliographic tools are needed, however, for those lecturers in small college situations without easy access to university facilities. The use of inter-library loan services among this group of lecturers was very low and perhaps may in part be attributed to difficulty in formulating precise requests as is necessary in utilizing inter-library loan facilities.

This is particularly true when the request is a subject one, rather than an exact reference from another source.

Generally speaking, the information problem for college of education lecturers is fairly easily defined. A relatively small amount of information is required, and while it should be comprehensive enough to prevent distortion, it should be small enough to be assimilated in a short time. Representative references, rather than comprehensive or exhaustive retrievals, are preferred.

This report also pointed up the necessity that an information system for educators take into account some behavior characteristics of this particular group. These include a relatively restricted amount of time for information gathering and using activities and a general lack of motivation to seek information.

Baughman (8), in an investigation of the information needs and problems involved in the operation of educational information centers also defined some behavioral characteristics of educators that should be taken into consideration in the design of STITE. The most serious problem of educators and their use of information is their lack of interest, concern, or motivation to read, to do research, and to seek out new and innovative ideas and methods. This attitude may be in part because of a shortage of time but it also reflects the personal information acquisition habits of educators who generally want to do little work, do not want to read more than one page, and do not want to synthesize work from several reports, Baughman claims. Neither are they aware of information services that are available nor are they trained to use such services in their decision making.

Borman and Mittman (12), recognizing the human factor in the use of information systems, asked the question of how a scholar can be induced to use computer capabilities in his search for information. After introducing a search facility to a group of students and a group of faculty members at Northwestern University, they found that faculty members soon lost interest in it and returned to traditional searching methods while the students continued to use it with enthusiasm. Thus the report concludes, " . . . .users of a new capability, such as interactive search, will try the system if properly motivated, but they will not incorporate this new capability into their normal behavior patterns unless there is a dramatic gain to be realized." The STITE system will face this problem of motivation among educators.

Another study of significance to STITE because of its findings about educators and their information needs is by Back (3). He reviewed studies on information dissemination from the stand-point of design requirements for on-line reference retrieval systems and concluded that, from among the categories of researchers, practitioners, managers, and educators, the educators and the researchers rely upon written channels for supplying information to a greater extent than practitioners and managers. The purposes for which information is gathered by educators are cited in Back's list:

<u>Purposes for Gathering Information</u>

1. Acquiring ideas for new work.
2. Supporting work in progress
   a. Gaining theoretical information
   b. Developing alternative approaches to problems
   c. Determining results of related work performed by others

d. Finding answers to specific questions (e.g., constant, tabulated value, formula, etc.)

e. Recommending procedures, apparatus or methodology

f. Evaluating an approach or a result

3. Keeping current

a. Being aware of workers in specific areas or problems

b. Being aware of developments in one's field

c. Being aware of developments in related fields

4. Developing competence

a. Brushing up on old specialty

b. Learning new specialty

5. Preparing educational materials

To achieve maximum utilization, Back maintained that a system must be directed at a particular audience and the activities of that audience, it must be designed so that the audience will accept and use it, and it must be as comprehensive as any other methods of reference retrieval.

A computer-based reference retrieval system would probably be most useful, according to Back, in satisfying the information needs of educators involved in the following activities:

1. Gaining theoretical information
2. Developing alternative approaches to problems
3. Determining results of related work performed by others
4. Answering specific questions about known documents

5. Keeping current on workers in specific fields

6. Developing confidence

7. Preparing educational materials

Back's inquiry into the comparative use of formal and informal sources of information shows that educators most frequently seek information in informal ways, such as personal indexes and files, conversation, correspondence, meetings, and journal scanning, as opposed to formal methods of a card catalog, a citation service, or a literature review or bibliography. He feels that this is so because informal methods usually deliver a few relevant references with the least amount of effort. Consequently, in order for a system to be widely accepted and used, it must be designed to retrieve the most relevant references with at least no more effort than is required by other methods, and he suggests five ways, based on the characteristics of informal methods, for making retrieval as easy as possible.

1. Allow the user to shape the interaction to fit his needs
2. Retrieve few irrelevant references
3. Furnish references to the appropriate type of document (i.e., a definition, a description of a process, a review article, etc.
4. Provide direction for further search
5. Deliver screened and evaluated references

The characteristics of formal sources of information also suggest to Back some ways to include their advantage into a system.

1. Strive for completeness in the area of coverage
2. Keep the data base as current as possible

3. Make the system public and conveniently available to all users

4. Have the data base created, maintained, and distributed centrally under the direction of a single, cognizant organization

5. Provide permanent storage for all references selected for the system

However, he continued to stress the importance of ease of use, and when that feature conflicts with completeness of output, the system must be designed to satisfy minimal effort requirements.

Since 1968 the University of Georgia Computer Center has provided a computer-based retrieval service for the purpose of supporting the instructional and research programs of the university system (15). A questionnaire survey to assess the impact of the service on the academic community indicated that more than half of the users of the center are faculty members, and among these faculty members, 4.1% reported that 100% of their time is spent in instruction. These respondents felt that the time-saving feature of this search facility was of primary importance to them, and they also indicated that it had allowed an increase in the subject areas that they regularly check.

Schumacher (33), in studying and making recommendations for an information system for a small college, outlined the activities of educators that require information, and they are: 1) course preparation 2) selecting reading assignments 3) independent study and honors projects 4) research projects and 5) administrative and committee assignments.

A report on the information needs of junior college educators by Mathies (27), stressed the necessity of incorporating into a system features that provide as much convenience and saving of time as the informal methods of information gathering.

3. Conclusions - User studies and surveys on information needs and information usage reveal some characteristics of the information needs of science educators, the group with which STITE is particularly concerned.

While the use of information sources by educators in general does not appear to be as extensive as it could be, science educators do utilize information resources, and the science educators are among the heaviest users of literature when compared with scientists in research and in industry.

The most frequent purposes for which information is sought are for keeping up-to-date by being aware of workers in specific areas or problems, being aware of developments in one's field and being aware of developments in related fields, and for answering a particular question or problem with specific data, i.e. a definition or a description of a process. Other reasons include brushing up on an old specialty or learning a new one, acquiring new ideas for work, determining related work by others, teaching students to use information systems, and preparing lectures and educational materials.

Problems encountered by science educators in information gathering activities center around their lack of time to locate and assimilate materials. Physical access to materials is a problem for some, as well as the difficulty of doing retrospective searches when bibliographic tools are unavailable.

Some behavioral characteristics of educators also generate difficulties that have bearing on their potential use of information systems. Restricted time for locating and assimilating information and the lack of motivation to use such resources are among the most important of these traits. The level of awareness of the availability of information sources seems to be low among this group, and there appears to be little effort to train educators to use information as a part of the decision-making process.

In conclusion then, based upon the information needs of science educators as they are reflected in user studies and surveys, it would seem that an information system such as STITE proposes should revolve around easy and rapid access to materials that are useful either for the purpose of keeping up-to-date or for answering particular questions with specific data. Low motivation and lack of time on the part of the science educator set the requirement for ease of use and rapid retrieval; definitions, descriptions of processes, and outlines are the kinds of specific information that he requires. Concerning keeping up-to-date, his need is for representative, not necessarily comprehensive, information on given topics with perhaps also some evaluation of materials. In this respect, a well-developed review literature would seem to be of great value to the science educator for it could present selections of up-to-date information on given topics without requiring a great amount of time for reading and assimilation. For keeping up-to-date, capitalizing on the advantages and popularity of informal sources of information, such as conversations with colleagues, could involve the inclusion in the information system of lists of authorities in a particular field with notes on their activities.

Some bibliographic tools for retrospective searching are needed but here again the requirement is for representative, rather than comprehensive, references.

III. THE QUESTIONNAIRE TO SCIENCE EDUCATORS

1. Introduction - User studies reveal some patterns of information need and use by science educators. However, since the interest of STITE is centered primarily on the utilization of existing information centers, further investigation into the actual use of these centers by science educators was desirable. This additional effort was made through a questionnaire survey aimed specifically at science educators in various American universities.

At present the main utilization of most scientific and technical information systems can be traced to the industrial and research communities (34), and the survey of previous studies indicates that the use of such information systems for educational purposes is probably minimal (8,12). Accordingly, the purpose of the questionnaire was to determine if science educators make use of science and technical information centers and under what conditions and for what reasons they do so. Furthermore, one of the important by-products of this inquiry might be to delineate more precisely than has been done in previous studies the information needs of science educators.

Within the context of the above objectives and because of the constraint to design an effective scientific and technical information transfer system for science educators, the present survey study has been prepared.

In designing the study, it was necessary to recognize the complexity of factors involved in the transfer of technical and scientific information and to reduce the investigation to a subset of this complex activity. It had been pointed out by previous investigators, Fearn and Melson (18), that information transfer is a complex social process wherein technology requirements, users needs, values, beliefs, and organizational structures play interactive roles to influence behavior. The interest of this inquiry is mainly in the aspect of user practices. More precisely, this study concentrates on the needs and actions of a subset of users, namely, science educators in American universities and colleges who might use science and technical information centers. In addition, the investigation is interested in a certain subset of facts about science educators on the university and college level who actually do use science and technical information centers. Because of the need to make factual statements, it was decided that an empirical approach, using the questionnaire method, would be most suitable for the purpose of this survey.

2. Statement of Hypotheses - The main objective of this research study was to test the following four hypotheses:

(a) Most science educators are not aware of the availability or the existence of science and technical information systems.

(b) Many science educators who are aware of the availability of science and technical information systems have no ready or easy access to them.

(c) Most of the science educators who have ready access available to them find that the information access tools are inflexible and unsatisfactory to use.

(d) Most of the science educators who access information from science and technical information centers find the information they provide to be of little use for their instructional purposes.

3. Rationale and Assumptions - The above stated hypotheses stem from the realization, supported by some intuitive pilot observations, that science and technical information centers are not well publicized in the science education community. Baughman (8), supports the idea of a lack of awareness of information centers among educators in general. This may be due to the fact that most science and technical information centers have been developed with the specific purpose of serving scientists in both academia and industry whose primary occupation is research and development and it has been in these science research areas that scientific and technical information centers have been mainly publicized. Information has been collected, organized, and disseminated for research purposes. Hence, those educators interested in accessing scientific and technical information centers perhaps find the organization and dissemination of information such that it is not of use for their immediate instructional needs. Given these facts, it would seem that science educators who have indeed attempted to use information from such centers have not been completely satisfied.

It was originally assumed that the display of information was presented in such a fashion that would allow effective use by educators for their instructional purposes. However, the specific suggestions by Back (3), Brittain (14), and Borman and Mittman (12), indicate that such may not be the case. The hypothesis that the access tools are not satisfactory in terms of the educator's needs in thus made.

Furthermore, on the basis of a limited sample of preliminary interviews, it seems evident that, even among science educators who know about the existence of science and technical information centers, the use of such centers is minimal. Even among those educators who use information from the centers for their research purposes, their use of information from the same centers for purely instructional purposes is practically non-existent. It had been earlier assumed that the information collected and organized by the centers was potentially valuable for instructional purposes, but evidently it is the structuring of the information by the centers and its format of dissemination which are the stumbling blocks to effective access and use by educators.

Hence, an information transfer system which can re-structure and re-formulate the large quantity of well-organized and stored research information into forms suitable for instructional purposes would act to increase and make more effective the use of science and technical information centers by educators. Here again, studies such as those by Back (3), and Borman and Mittman (12), bear out this hypothesis.

4. Research Method - Having selected and specified a set of hypotheses, it was important to consider and utilize an appropriate technique for testing those hypotheses. Many of the questions related to the hypotheses have not been previously studied so it was not possible to analyze already existing data. The five most common methods for conducting user surveys are questionnaires, interviews, observations, the diary method, and analysis of already existing data; the most common and generally used approach to collecting factual data relative to user needs is that of a questionnaire.

It was necessary that the sample come from a large population of science educators from schools and departments spread across the country in order to be able to make a fair and broad generalization about the use of science and technical information systems. It was also necessary that the sample itself be large because, having assumed that most science educators have seldom accessed science and technical information systems, it was necessary to insure that a sizable sub-sample, though comparatively small, would have indeed used centers and would thus provide a meaningful set of observations on their use. Because of the scope of the survey both geographically and numerically, the mailed questionnaire, rather than other methods, seemed to be the most practical survey technique.

The questionnaire method has some pointed drawbacks. One disadvantage is the possibility of a response rate so low that no meaningful conclusion can be drawn. This will hopefully be overcome by the large sample of science educators who receive the questionnaire.

Another drawback of the mailed questionnaire is that there is no way that the investigator can determine the state of mind of the respondent and its possible effects on his answers to the questions. Again, while the respondent's state of mind at the time might affect his answers, it does not seem that it would have a determining influence on his response to the questions specifically related to the four hypotheses of the STITE questionnaires since they were designed to elicit statements of fact rather than opinion.

Another criticism sometimes made about the mailed questionnaire method is that the questioner has no way of knowing whether the respondent understands the question. The attempt was to take care of this criticism in the preparation of the questionnaire by wording each question as precisely and as specifically as possible, and a letter explaining the purpose of

STITE and the meaning of scientific and technical information systems accompanied each questionnaire.

The questionnaire was as short as practical. It covered all of the information desired with the smallest number of questions possible and was estimated, on the basis of pre-testing, that a potential respondent would take no more than ten minutes to complete it.

Finally, the sequence of questions was designed to be logically ordered. In organizing the questions, the respondents were divided into two categories, (a) those who use science and technical information systems, and (b) those who do not use such systems. This division permitted three categories of questions based on each type of respondent. The first category of questions was directed only to those who actually use science and technical information systems. The second category was directed to those who do not use such systems, and the last category of questions was directed to both types of respondents, users and non-users.

Having specified the above mentioned categories, the questionnaire was organized accordingly. The first question was asked of every respondent as it related to familiarity with systems. The second question, directed to respondents who are familiar with scientific and technical information systems, asked whether they use or do not use such systems. Then the next set of questions was directed to those who have in the past used science information systems. The questions covered such topics as the purposes for which science information systems are used, the frequency of use, the materials needed, the conditions under which the system and its information might become more useful, the kinds of materials that are requested from science and technical information centers, the degree of satisfaction with respect to the service and the material, and the ease of access to science and technical information systems.

Finally questions were asked of both users and non-users. These were in the form of open questions which allow the user to air his free opinions.

In total, the questionnaire was made up of eleven questions with clear and precise instructions on how to proceed in order to answer each of the applicable questions.

A copy of the questionnaire and the accompanying letter appear in Appendix A and Appendix B.

5. Sampling and Distribution of the Questionnaire - A stratified random sampling technique was used in selecting the subjects for the questionnaire. Two thousand science educators were selected randomly from colleges and universities in the United States. The list of colleges and universities was abstracted from the reference book, American Universities and Colleges, and the individual faculty names were obtained by using general catalogs of the colleges and universities selected. The sampling procedure is described in the following:

1. It was decided to include all three major scientific divisions as suggested in American Universities and Colleges, namely biological, physical, and social sciences.

2. It was decided to include both the traditional disciplines, as well as inter-disciplinary programs. In the biological sciences, the following fields were selected:

Biochemistry

Botany

Genetics

Microbiology

Physiology

Zoology

In physical sciences, the following fields were selected:

Astronomy

Chemistry

Aeronautical Engineering

Civil Engineering

Electrical Engineering

Mechanical Engineering

Statistics

Physics

In the social sciences, the fields selected were as follows:

Anthropology

Economics

Library Sciences

Psychology

Sociology

3. Approximately 100 faculty members were randomly selected from each selected field to receive the questionnaire.

4. Within each field, a list of colleges and universities that offer such a discipline was obtained by using the listings in American Universities and Colleges. Around 108 institutions were randomly selected from the list.

5. The general catalogs of the selected institutions were obtained. Between five to ten faculty names were selected from the faculty list of the chosen department or program. The selection of the individual names was at random. Therefore,

the proportion of the faculty ranks in terms of full professor, associate professor, assistant professor and instructor reflects the actual composition of the faculty population in the field.

6. A questionnaire along with an individually-addressed letter was sent to the selected faculty members by mail. A self-addressed return envelope was included. A total of 311 individual departments were selected from 311 colleges and universities. These schools are distributed in 43 states. The following disciplines were represented by this selection:

Biochemistry

Botany

Genetics

Microbiology

Physiology

Zoology

Astronomy

Chemistry

Aeronautical Engineering

Civil Engineering

Electrical Engineering

Mechanical Engineering

Statistics

Physics

Anthropology

Economics

Library Sciences

(Cont.)

Psychology

Sociology

7. Index cards that carry the name of the potential respondent, has subject field, and his university, were prepared as the questionnaires were addressed. A number was assigned to each respondent and that number was indicated on his questionnaire and on the corresponding index card. In this way, replies can be identified and arranged in various meaningful groupings, i.e. by subject field, by university, by geographical area, etc.

I.V. INQUIRY TO INFORMATION CENTERS

In order to secure and analyze any already existing data, information was requested from 69 centers across the country concerning the utilization of these centers by science educators. Of particular interest were any existing user studies that might include findings pertinent to science educators.

Centers receiving the inquiry were selected from the list that appears in the first progress report of this project (34).

Appendix C contains a copy of this letter to science and technical information centers, and the list of those centers receiving the inquiry appears in Appendix D.

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(Note: The notation, such as ED068101 or ED047736, which follows some entries in this bibliography refers to the number assigned that report by the Educational Resources Information Center (ERIC).)

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PART TWO

INTERACTIVE STITE INTERFACE SYSTEM FOR EFFECTIVE USE OF INFORMATION STORES

PART TWO

INTERACTIVE STITE INTERFACE SYSTEM FOR EFFECTIVE USE OF INFORMATION STORES

Pranas Zunde

I. INTRODUCTION

As noted in Part One of this report, existing science and technical information systems have limited utility for educators because, among other things, they do not allow the user to shape the interaction with those systems to fit his needs and because the existing search mechanisms do not provide directions for further search. Although these are not the only factors which limit the usefulness of science and technical information systems to educators, they seem to be certainly of great importance. Hence, one of the tasks of the ongoing research was to develop, as a part of the STITE system, an interface mechanism which would help the educator to structure selected types of tasks which are characteristic for this profession and which would induce him, through various automated procedures, to make better use of existing information resources.

The underlying idea of the proposed interface system is to store in the system certain amounts of information in highly structured modular form, relevant to specific needs of various groups of educators. The modules in the system are manipulable and can be assembled into various sequences geared to various tasks which educators might be expected to perform in their profession.

The essential features of such a modular interface system, which will provide the basis for the design or a small experimental program, are reported in the sequel. The subject matter of the experimental design has been somewhat arbitrarily limited to graph theory.

II. MODULES

1. Definition and Description

A module is a manipulable unit of information of which outputs of the STITE system are constructed. Usually a module will describe, display, illustrate or define a single object or entity such as a thing, event, concept, relation, or anything else to which attention can be directed.

Characteristic examples of modules are:

(1) portions of natural language texts

(2) illustrations

(3) diagrams

(4) tables

(5) problems (solved or unsolved)

(6) examples

(7) pieces of music, etc.

In a broad sense, a module is comparable to a record of a file system. Its length or size might vary depending on the nature of discourse, context, type of materials, etc.

The modules are assigned codes to distinguish them according to (1) The form in which material is presented in the module, (2) The type of material presented, and (3) The level of difficulty of the material contained in the module.

2. Descriptors of Module Content

Associated with every module is a set of descriptors which serve as indices of the information content of the modules. This set consists of two categories of descriptors, CATEGORY A and CATEGORY B.

Descriptors of CATEGORY A of a module are names of objects (things, concepts, events, etc.) which are being defined, described, or otherwise explicated or demonstrated by a particular module. It might be desirable, although not absolutely necessary, to have only one descriptor of CATEGORY A associated with a module. If t_i, $i = 1,2,\ldots,m$ is a descriptor, then $t_i(A)$ shall denote the descriptor of category A.

Descriptors of CATEGORY B are terms which are used to define, describe, or otherwise explicate or demonstrate an object named by a descriptor of category A. If t_i, $i = 1,2,\ldots.,m$ is a descriptor, then $t_i(B)$ denotes that this descriptor belongs to category B.

It should be noted that one and the same descriptor can, and in many instances will, be a descriptor of category A for one module and a descriptor of category B for some other module.

Selection of descriptors is controlled with respect to admissible types, grammatical structures, synonyms, etc. The set of admissible descriptors with the rules of descriptor formation and transformation constitute the descriptor language of the STITE system.

An example of a module with descriptor of category A and B is shown in Figure 1.

Matroid theory is simply the study of sets with independent structures' defined on them, generalizing not only properties of linear independence in vector spaces, but also several of the results in theory. However, matroid theory is far from being 'generalization for generalization's sake'; on the contrary, it gives us a deeper insight into several graphtheoretical problems as well as including among its applications simple proofs of results in transversal theory which are awkward to prove by more traditional methods. We believe that matroid theory has an important role to play in the development of combinatorial theory in the coming years.

A	B	C	WIL/1/20
matroid theory	set		
	independence structures	F	1
	linear independence		
	vector space	H	2
	transversal theory		
	combinatorial theory	D	1
	generalization		

Fig. 1

3. Predetermined Sequencing of Modules

In some instances it might be desirable to have the capability to restore sequences of modules as they appeared in the original document from which modules were constructed. On the other hand, users of the STITE systems might want to retain, for easy construction, certain sequences of modules which they have constructed in the process of their interaction with STITE. Therefore, modules are assigned special codes which will permit ordering them sequentially by author's or user's preference. This code shall be called tested link code. Since more than one code of this kind may be associated with a module, the family of such codes assigned to the module will be called tested link code set.

A tested link code consists of alphabetical and numerical parts. The alphabetical part is a string of three characters and serves the purpose of identifying the individual author or user who generated a tested link involving that particular module. Control is to be exercised to insure that every such individual has a distinct identification code. The numerical portion of the code consists of a two digit code identifying a particular sequence, followed by a three digit code which serves as an index of the module's position in a particular sequence.

Whenever a set of modules which has a meaningful order reflecting the sequence of materials proposed by the author or system's user is prepared for input into the STITE system, a tested link code is assigned at the input stage and becomes part of the initial profile of a module.

Example of a tested link code: "WIL/3/101", with "WIL" being the identifier of the author of a book from which the module was constructed, "3" indicating a particular sequence out of all sequences of modules associated with the author "WIL", and "101" any module being the index of that module in the sequence "3" of modules extracted in a particular order from that source.

Sequences of modules which are identified in the above described fashion induce in a natural way certain order relations on the set of modules. In general, there will be as many distinct order relations as there are distinct sequences of tested link codes associated with the originators of sequences of modules. These order relations shall be called tested link, or simply link relations. More specifically:

DEFINITION: Let m_i, m_j be modules, $i,j=1,2,\ldots n$, $i\neq j$. Module m_i is link related to module m_j if and only if module m_i and module m_j have link codes with identical author and sequence identifiers and nonempty module position indices (i.e. last three digits of the code).

A link relation, which has just been defined, will be denoted by $R_{LK(\cdot)}$, with the notation (·) indicating that any author and sequence identifier used as part of a tested link code can be substituted for the dot in parenthesis to specify a particular link relation.

4. Classification of Modules

Every module in the system is classified according to form in which the materials contained in it are presented, type of materials, and level of difficulty.

4.1 Classification by Form - In the experimental STITE system, modules will be admitted containing materials only in such form as can be displayed on a CRT screen or printed in line or graphics. Every module will be labeled by a code consisting of the alphabetical character "F", and natural number to identify the form in which materials are contained. Specifically, the following classes of modules with respect to the form of materials are considered:

F1 - material in natural language form

F2 - diagrams, graphs, flow charts

F3 - tables

Every module will be assigned to one, and only one, of the above classes, so that the set of all modules is partitioned into disjoint subsets with regard to the form of materials.

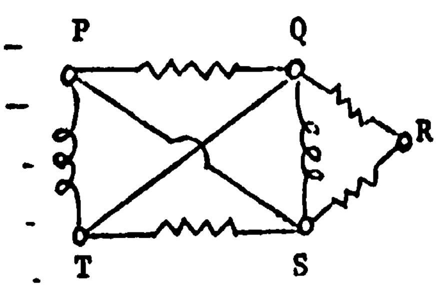
The relation thus defined shall be called form relation and denoted by R_F.

Examples of modules of class F1, F2, and F3 are given in Fig. 2, 3, and 4.

The study of directed graphs (or digraphs, as we shall usually abbreviate them) arises out of the question, what happens if all the roads are one-way streets? An example of a digraph is given in WIL/2/10 the directions of the one-way streets being indicated by arrows; (in this particular example, there would be utter chaos at T, but that does not stop us from studying such situations!) Note that if all of the streets are one-way, then we can obtain a digraph by drawing for each two-way road two directed edges, one in each direction.

A	B	C WIL/2/12
directed graph	digraph directed edge one-way street	F 1 H 2 D 1

Fig. 2



A	B	C WIL/1/3
graph	electrical network	F 2 H 7 D 1

Fig. 3

Calculated and experimental values of the standard heat of formation of several hydrocarbons

Hydrocarbon	*Calculated*	*Experimental*
	H°_{298} in kilocals mole^{-1}	
propane	26.01	24.82
n-butane	30.81	30.15
n-pentane	35.62	35.00
n-hexane	40.42	39.96
n-heptane	45.22	44.89
n-octane	50.02	49.82
isobutane	32.32	32.15
2-methylbutane	36.69	36.92
2,2-dimethylpropane	39.70	39.67
2-methylpentane	41.49	41.66
3-methylpentane	41.06	41.02
2,2-dimethylbutane	43.64	44.35
2,3-dimethylbutane	42.14	42.49
2-methylhexane	46.29	46.60
3-methylhexane	45.86	45.96
3-ethylpentane	45.43	45.34
3-ethylhexane	50.23	50.40

<u>A</u>	<u>B</u>	<u>C</u>	ROU/1/22
hydrocarbon	value standard heat	<u>F</u>	3
		<u>H</u>	7
		<u>D</u>	1

Fig. 4

4.2 <u>Classification by Type of Material</u> - Every module will be further classified by the type of material it contains in the following categories:

H1 - definitions

H2 - informal descriptions of objects, events, concepts, illustrative explications, etc.

H3 - theorems and deductive proofs

H4-1 - solved problems

H4-2 - unsolved problems

H5 - valuations

H6 - comments, i.e. introduction, conclusion

H7 - types of materials other than those covered in #1 through #5

Every module stored in the STITE system will be designed so that it can be assigned to one and only one of the above classes so that the set of the classes (H1, H2, H3, H4-1, H4-2, H5, H6), (H7) forms, too, a partition of the set of all modules.

DEFINITION: Modules m_i, m_j, $i, j = 1, 2, \ldots n$, are said to be related in type if and only if they are labeled as belonging to the same type class H_i, $i = 1, 2 \ldots 7$. The relation itself shall be called <u>type relation</u> and denoted by R_H.

Examples of modules of various types are given below.

We shall define a simple graph G to be a pair (V(G),E(G)), where V(G) is a non-empty finite set of elements called vertices (or nodes, or points), and E(G) is a finite set of unordered pairs of distinct elements of V(G) called edges (or lines); V(G) is sometimes called the vertex set and E(G) the edge-set of G. For example WIL/1/12 represents the simple graph G whose vertex-set V(G) is the set (u, v, w, z), and whose edge-set E(G) consists of the pairs (u,v), (v,w), (u,w), and (w,z). The edge (v,w) is said to join the vertices v and w; note that since E(G) is a set, rather than a <u>family</u>*, there can never be more than one edge joining a given pair of vertices of a simple graph.

*We use the word "family" to mean a collection of elements, some of which may occur several times; for example, (a,b,c) is a set, but a,a,a,b,c,c,) is a family.

<u>A</u>	<u>B</u>	<u>C</u> WIL/1/25
simple graph	vertex	
	node	<u>F</u> 1
	point	
	edge	<u>H</u> 1
	line	
	vertex-set	<u>D</u> 1
	edge-set	
	family	

Fig. 5

It turns out that many of the results which can be proved about simple graphs may be extended without difficulty to more general objects in which two vertices may have more than one edge joining them. In addition, it is often convenient to remove the restriction that any edge must join two distinct vertices, and to allow the existence of loops, i.e. edges joining vertices to themselves. The resulting object, in which loops and multiple edges are allowed, is then called general graph--or simply a graph (see WIL/1/30. We emphasize the fact that every simple graph is a graph, but not every graph is a simple graph.

A	B	C WIL/1/29
graph	general graph	F 1
	vertex	
	edge	H 2
	loop	
	multiple edge	D 1

Fig. 6

<u>Theorem.</u> Let G be a simple graph on n vertices; if G has k components, then the number m of edges of G satisfies

$$n - k \leq m \leq \tfrac{1}{2}(n - k)(n - k + 1).$$

<u>Proof.</u> To prove that $m \geq n - k$, we use induction on the number of edges of G, the result being trivial if G is a null graph. If G contains as few edges as possible (say m_o), then the removal of any edge of G must increase the number of components by one, and the graph which remains will have n vertices, k + 1 components, and $m_o - 1$ edges. It follows from the induction hypothesis that $m_o - 1 \geq n - (k + 1)$, from which we immediately deduce that $m_o \geq n - k$, as required.

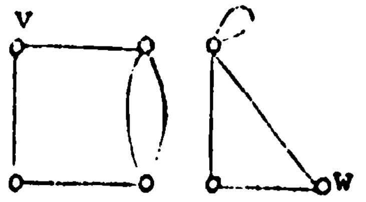
To prove the upper bound, we can assume that each component of G is a complete graph. Suppose, then, that there are two components Ci and Cj with ni and nj vertices respectively, where $ni \geq nj > 1$. If we replace Ci and Cj by complete graphs on ni + 1 and nj - 1 vertices, then the total number of vertices remains unchanged, and the number of edges is increased by

$$\tfrac{1}{2}((ni + 1)ni - ni(ni - 1)) - \tfrac{1}{2}(nj(nj - 1) - (nj - 1)(nj - 2))$$
$$= ni - nj + 1$$

which is positive. It follows that in order to attain the maximum number of edges, G must consist of a complete graph on n - k + 1 vertices and k - 1 isolated vertices; the result now follows immediately.

<u>A</u>	<u>B</u>	<u>C</u> WIL/2/118
enumeration of edges	vertex component	<u>F</u> 1
		<u>H</u> 3
		<u>D</u> 1

Fig. 7



A	B	
path		C WIL/1/15
		F 2
		H 7
		D 1

Fig. 8

Show that (1) the automorphisms of G form a group under composition (the automorphism group T(G)G of G); (ii) the groups T(G) and T(C) are isomorphic; (iii) T(kn) is the summetric group on n elements. Find the automorphism group of Kmn and give an example of a graph whose automorphism group is cycles of order three.

A	B	
automorphism	automorphism group symmetric group element dihedral group	C WIL/2/89 F 1 H 4-2 D 1

Fig. 9

4.3 <u>Classification by The Level of Difficulty of Materials</u> - Finally, every module is classified by the level of difficulty of material contained in the module into one of the following three exclusive categories.

D1 - introductory level

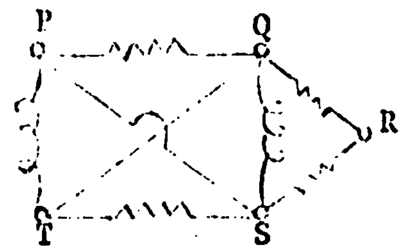
D2 - advanced level

D3 - unspecified

It is realized that there are no formal, objective criteria for classifying modules by level of difficulty of materials contained in the modules. In many instances, the decision as to the level of difficulty will be made by the educator using the STITE system, who will be permitted to reclassify a module in this respect at his discretion. Other cues for level of difficulty classification can be found in comments of the author of the documents from which the module is adopted, comments of reviewers of such documents, etc.

DEFINITION: Modules m_i, m_j, $i = 1, 2, \ldots n$ are related by level of difficulty if and only if they have been assigned to the same class. D_k, $k = 1, 2, 3$. The relation itself shall be called level of difficulty relation and denoted by R_D.

Examples of modules of various levels of difficulty are given below.



A	B	C	WIL/1/3
graph	electrical network	F	2
		H	7
		D	1

Fig. 10

5. Profile of a Module

As has already been stated, every module which is stored in STITE has descriptors of categories A and B and eventually a tested link code assigned to it and is furthermore classified by form, type, and level of difficulty. Collectively, this constitutes what will be henceforth referred to as the profile of a module. More specifically:

DEFINITION: The profile prof(m) of a module m is a sixtuple $\langle T_A, T_B, C, F_i, H_j, D_k \rangle$, where

T_A = set of descriptors of category A assigned to the module m

T_B = set of descriptors of category B assigned to the module m

C = tested link code set

F_i = form of the module m, i=1,2,3

H_j = type of module m, j=1,..., 7

D_k = level of difficulty of module m, k=1,2,3

III. RELATIONS ON SETS OF MODULES

1. Semantical Relations on Descriptors of Definitional Modules

Relations of a semantical nature are recognized on the set of descriptors assigned to definitional modules and explicitly stored in the system. These relations in turn induce in a natural way relations in the set of modules. The latter will be discussed in Section III. 2.

As before, let T_A be the set of descriptors of category A and T_A the set of descriptors of category B. Then $T = T_A \cup T_B$ is the set of all descriptors associated with definitional modules. This set of descriptors is called STITE vocabulary.

Several relations which are based on the interpretation of the meaning of terms in STITE vocabulary will now be defined.

DEFINITION: Let $t_i, t_j \in T$ be arbitrary terms in the STITE vocabulary. Let term t_i implies term t_j, $t_i \rightarrow t_j$, if the extension of the concept named by term t_j includes the extension of the concept named by term t_j is contained in the intension of the concept named by term t_i. This relation shall be called semantic implication and denoted by S_{IM}.

LEMMA. The semantic implication relation S_{IM} is reflexive and transitive, but, in general, not symmetric.

Example:

(dog, animal) $\in S_{IM}$

(metric function, quasimetric function) $\in S_{IM}$

Another relation of semantical nature is the similarity relation. More specifically:

DEFINITION: Let $t_i, t_j \in T$ be arbitrary terms of the STITE vocabulary. Term t_i and t_j are similar in meaning if, and only if, the extensions or the intensions of concept named by these terms have elements in common and neither term t_i implies t_j nor term t_j implies term t_i. The relation thus defined will be called <u>semantic similarity</u> relation and denoted by S_{IM}.

LEMMA: Semantic similarity relation is reflexive and symmetric, but in general, not transitive.

Examples of elements of semantic similarity relation are:

(bird, flying object) $\in S_{SIM}$

(complete graph, weighted graph) $\in S_{SIM}$

2. Relations on Modules Induced by Semantic Relations on Descriptors

Semantic relations on the set of descriptors induce several important relations on the modules in the STITE system.

Let m_i and m_j, $i,j=1,2,\ldots n$, be modules and let $t_i(A)$ be a term of class A associated with the module m_i and $t_j(A)$ be a term of class A associated with the module m_j. Let $(m_i,m_j) \in R_{GEN}$ if and only if $[t_i(A), t_j(A)] \in S_{IM}$. Here the relation R_{GEN} shall be called generalizing relation.

The interpretation of the generalizing relation is simple: if

$(m_i,m_j) \in R_{GEN}$, then the module m_j defines, describes, or illustrates a concept which is more general than the concept defined, described, or illustrated by the module m_j.

The converse relation, $R^{-1}GEN$, can be meaningfully interpreted as in the relation leading from generic to specific.

Another relation is that of explicational amplification. Module m_j explicationally amplifies module m_i, if and only if there is a term $t_i(B)$ of class B associated with the module m_j which semantically implies term $t_j(A)$ of class A associated with the module m_j. This relation is denoted by R_{EXA}. Thus $(m_i, m_j) \in R_{EXA}$ if and only if $[t_i(B),t_j(A)] \in S_{IM}$.

Furthermore, two modules m_i and m_j, $i,j = 1,2, \ldots, n$ are <u>meaning</u> associates, and denoted $(m_i,m_j) \in R_{MA}$, if and only if a term $t_i(A)$ of class A associated with module m_i is semantically similar to some descriptor $t_j(A)$ associated with the module m_j, i.e. if and only if $[t_i(A), t_j(A)] \in S_{SIM}$.

3. <u>Relations on Modules Induced by Formal Relations on Descriptors</u>

Relations on the set of modules stored in STITE are induced also by the formal relations which have been defined on the set T on descriptors, i.e. or the vocabulary of the system. One such category of relations is explicational relations.

DEFINITION: Let m_i and m_j be arbitrary modules of STITE. m_i is explicationally related to m_i if there exists a descriptor t such that $t \in T_i(A)$ and $t \in T_j(B)$, where $T_i(A)$ is the set of descriptors of category A associated with module m_i and $T_j(B)$ is the set of descriptors of category B associated with module m_j. This relation is denoted by R_{EXP}.

Corollary: A connected graph is Eulerian if and only if its edge-family can be split up into disjoint circuits.

A	B	C	WIL/1/54
Eulerian graph	connected graph edge-family	F	1
	disjoint circuits	H	3
		D	1

Fig. 11

Let V be the vector space associated (in the sense of exercise 2j) with a graph G. Use corollary 6c to show that if C and D are circuits of G, then their vector sum C + D may be written as an edge-disjoint union of circuits; deduce that the set of such unions of circuits of G forms a subspace W of V (called the circuit subspace of G.)

A	B	C	WIL/1/67
circuit subspace	vector space Eulerian graph	F	1
	edge-disjoint union circuit	H	4 - 2
		D	1

Fig. 12

DEFINITION: Consider arbitrary modules m_i, m_j; $i,j=1,2...n$. We shall say that m_i and m_j are <u>contextually related</u> if and only if there exists a descriptor $t \in T$ such that $t \in T_i(B)$ and $t \in T_j(B)$, i.e. such that t is a descriptor of category B contained in the profile of both modules m_i and m_j. This relation is denoted by R_{CON}.

The contextual relation induces a variety of groupings of the set of modules, depending on a more specific criteria involving the associated descriptors. For instance, a particular descriptor $t \in T$ might be selected and modules grouped into two classes: class of modules having descriptor t as an element of T(B) in their profiles and a class of modules which do not have descriptors t as an element of T(B) in their profiles. On the other hand, the modules may be grouped into one class if they have some descriptor of category T(B) in common.

An example of contextually related modules #13 and #14 is given below:

> Matroid theory is simply the study of sets with 'independence structures' defined on them, generalizing not only properties of linear independence in vector spaces but also several of the results in graph theory. However, matroid theory is far from being 'generalization's sake; on the contrary, it gives us a deeper insight into several graphtheoretical problems as well as including among its applications simple proofs of results in transversal theory which are awkward to prove by more traditional methods. We believe that matroid theory has an important role to play in the development of combinatorial theory in the coming years for this reason.

A	B		
matroid theory	set	GRAPH THEORY	
	independence structure	C	WIL/1/20
	linear independence		
	vector space	F	1
	transversal theory	H	2
	combinatorial theory		
	generalization	D	1

Fig. 13

We shall investigate various combinatorial problems, including the celebrated 'marriage problem' which asks under what conditions a collection of boys, each of whom knows several girls, can be married off in such a way that each boy marries a girl he knows. This problem can be easily expressed in the language of transversal theory, a very important branch of combinatorial mathematics. It will turn out that these topics are closely related to the problem of finding the number of paths connecting two given vertices in a graph or digraph, subject to the restriction that no two of the paths have an edge in common.

<u>A</u>	<u>B</u>		
combinatorial theory	marriage problem transversal theory path	<u>C</u>	WIL/1/18
		<u>F</u>	1
		<u>H</u>	2
		<u>D</u>	1

Fig. 14

DEFINITION: Modules m_i and m_j, $i,j = 1,2, \ldots, n$ are <u>homonymicly related</u> if there exists a descriptor $t \in T$ such that $t \in T_i(A)$ and $t \in T_j(A)$, where $T_i(A)$ and $T_j(A)$ are sets of terms of category A associated with modules m_i and m_j, respectively.

We shall denote a homonymic relation on the set of modules by R_{HOM}

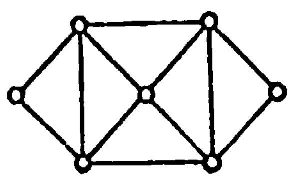
Intuitively, whenever any two modules are homonymicly related, they either explicate a particular concept in different terms, or explicate possible different applications of the same concept, or explicate concepts which are different concepts but which are referred to by the same name (descriptor).

Examples of modules which are homonymically related are given below.

Problems on Eulerian graphs frequently appear in books on recreational mathematics - a typical problem might ask whether a given diagram can be drawn without lifting one's pencil from the paper and without repeating any lines. The name 'Eulerian' arises from the fact that Euler was the first person to solve the famous Konigsberg bridge problem which asked, in effect, whether the graph in WIL/1/42 has an Eulerian path (it hasn't!).

A	B		
Eulerian graph	recreational mathematics Euler Konigsberg bridge problem	C	WIL/1/49
		F	1
		H	2
		D	1

Fig. 15



A	B		
Eulerian graph	connected graph closed path Eulerian path	C	WIL/1/48
		F	2
		H	7
		D	1

Fig. 16

4. Relational System of Modules

Let M denote the set of all modules which are stored in STITE. Let R_i, $i = 1,2, \ldots, n$ be a set of binary, trinary, etc. relations defined on the set M. The mathematical object $\langle M, R_1, R_2, \ldots, R_n \rangle$ shall be called the relational system of modules of STITE.

In the preceeding section, we have already defined the following relations on the set M of modules:

$R_F \equiv$ form relation (see I. 4.1)

$R_H \equiv$ type relation (see I. 4.2)

$R_D \equiv$ difficulty relation (see I. 4.3)

LEMMA. Relations R_F, R_H, and R_D are equivalence relations on the set of modules M.

From the relations R_F, R_H, and R_D, other useful relations can be obtained by the so called refinement process.

DEFINITION: Let $\hat{R}$ and S be arbitrary relations. The product RS of the R and S is the relation RS so that

$$RS =' \{(x,y) \mid \forall x,y \, \exists z \quad (x,z) \in R \text{ and } (z,y) \in S\}$$

DEFINITION: An equivalence relation R is a refinement of the equivalence relation R if and only if $a \in R \Rightarrow a \in R$ for all $a \in \hat{R}$.

LEMMA. The product relations $R_F R_H$, $R_F R_D$, and $R_H R_D$ are requivalence relations and are refinements of the relations R_F and R_H and R_F and R_D, and R_H and R_D, respectively.

LEMMA. The product relation $R_F R_H R_D$ is an equivalence relation and is a refinement of the relations $R_F R_H$, $R_F R_D$, $R_H R_D$, R_F, R_H, and R_D.

LEMMA. $R_F R_H R_D = R_F R_D R_H = R_H R_D R_F = R_H R_F R_D = R_D R_F R_H = R_D R_H R_F$.

Other relations on the set M of modules, which have been already defined and which are part of the relational system of modules of STITE, are:

R_{SEQ_i} $\equiv$ Test-linked sequencing relations - = 1,2, ...,k.

R_{EXP} $\equiv$ Explicational relation

R_{CON} $\equiv$ Contextual relation

R_{HOM} $\equiv$ Homonymy relation

R_{EXA} $\equiv$ Explicational amplification relation

R_{MA} $\equiv$ Meaning associate relation

Further details of the relational system of modules are in the process of development together with the experimental STITE interface system.

IV. PROCEDURES USED IN PREPARING EXPERIMENTAL MODULES

For the experimental STITE interface system, a set of modules was prepared with the goal of providing an introduction to the subject of graph theory. Most modules were extracted from the book, Introduction to Graph Theory by Wilson, which was chosen because it presents the necessary type of subject matter at the desired level of difficulty.

Modules were constructed from excerpts from the text. Modules in natural language form were selected of about 20 to 100 words in length.

Descriptors of both categories A and B were extracted from the text of the modules. These were written on the index card with the concept in accordance with the already outlined definitions (i.e., A = the name of the concept, B = modifying or descriptive words and terms, C = the code for the source of the material, F = the form of the material, H = the type of material, and D = its level of difficulty.).

Certain general rules for editing the text were followed in module preparation.

1. Statements are prepared as spoken presentations, rather than as written ones. Consequently such phrases as "in the previous chapter," "the reader will note," and "terms in bold face type" must be deleted and the text rearranged when necessary for clarity and completeness.

2. Different types of materials, even if they describe the same concept, are separated. For example a definition of a bipartite graph that is followed in the text by an illustration of such a graph must be divided so that the definition comprises one module and the illustration another.

3. References from one module to another use the author code number of the module referred to and not the wording of the text. "Graphs containing no loop or multiple edges (such as the graph in Fig. 15)" would appear as "graphs containing no loops or multiple edges (such as the graph in WIL/1/11)".

4. Terms for A and B are nouns. Adjectives may be included when they are a part of the name of the concept, as in the case of "planar graph" or "disconnecting set", but the basic term is in noun form. (In a few instances it is necessary to include a modifying phrase, such as "collection of <u>points</u>" or number of <u>edges</u>, but this usage should be avoided whenever possible.)

5. All terms used are singular, not plural, in form. Even when the text uses the plural, as in "the study of directed graphs," the A or B term would be "directed <u>graph</u>". (Occasionally there is a term which, when used in the singular, is meaningless. Such a term would be "multiple edges" or "adjacent vertices". In these cases, the term may be used in the plural form but here again, this exception to the rule should be avoided whenever possible.)

6. Be consistent in the use of terms when the same name or concept appears in different modules. For example, do not use "vertex" in one module and "point" in another"

7. In some cases there may be no "B" term in a given module, but there is always an A term.

8. Each module should be a complete unit and should not refer to any other module except in cases in which there is a specific reference by module number to another. To illustrate, phrases within the text such as "the graph we have been discussing so far" and "such graphs will be discussed later" should be deleted. However, any specific references such as "by means of points and lines as in <u>WIL/1/5</u>" and "the graph in <u>WIL/1/8</u> can also represent" are retained in the text and also listed under Term B.

PART THREE

STRUCTURING OF OUTPUTS OF THE INTERFACE SYSTEM BY TYPES OF REQUESTS

PART THREE

STRUCTURING THE OUTPUTS OF THE INTERFACE SYSTEM BY TYPES OF REQUESTS

Albert N. Badre

1. Variations in Levels of Requests

Two types of request variations are identified: (a) between-request variation and (b) within-request variation. The class of between-request variation constitutes those tasks that an educator considers necessary to "proper" teaching. The sixteen task possibilities suggested in the last report are examples of the between-request variance classification. Under this category of requests, the difference in queries corresponds to the difference in tasks. For example, a query for generating a course outline is different from one that generates a narrative presentation.

In the class of within-request variation, the same question is asked in different ways and at different levels of definability. Take, for example, the request: Retrieve a sub-course on Eulerian graphs. This request may be made at (a) various levels of content, for (b) different types of clients, at (c) various levels of difficulty, and (d) different modes of presentation. Note that while the request may be different in correspondence with various combinations of the stated levels, those differences are over the same task. For instance, a request for a subcourse on Hamiltonian graphs, while different in content from a request for a subcourse on equilateral triangles, is the same task-type. The distinctions relative to the within-request variation will be emphasized here.

The following are examples of each of the above-stated levels.

1.1 Levels of Content

Retrieve:

Q1 a sub-course on Eulerian graphs

Q2 a sub-course on Eulerian graphs, but include an explanation of graph.

Q3 a sub-course on Eulerian graphs to a group of students who know the meaning of graph.

Q4 Retrieve a sub-course on a set of concepts, A, but exclude an explanation of k terms in net B, such that k = {0,1,2. . .}.

1.2 Levels of Users

Q5 Retrieve (Q1) (this refers to (1) above) for a group of chemists.

Q6 Retrieve (Q2) for a mixed group of chemists and electrical engineers.

Q7 Retrieve (Q1) for a group of non-scientists.

Q8 Given (Q4) apply to group g.

1.3 Levels of Difficulty

Q9 Retrieve (Q1) at a moderate level of difficulty.

Q10 Given (Q6) retrieve (Q2) at an elementary level of difficulty.

Q11 Given (Q4) or (Q8), apply to level of difficulty f.

1.4 Levels of Presentation

Variations in requests stemming from differences in modes of presentation are associated with the following different types of modules.

1.4.1 Motivational - This type of module describes the content of a course which is peripheral to the content of the lesson. It is motivational. The author's purpose is primarily to introduce the lesson in order to capture the student's attention and interest. Ordinarily with each module we associate a central concept and a set of terms that are used in explaining that concept. The central concept associated with this type of module is characterized by the name of a topic.

1.4.2 Illustrative Explication - This class of module contains illustrative explication of concepts. Here the concept is not defined formally or explained analytically. It is explained by way of concrete examples.

1.4.3 Definitional - These are modules in which the concept is explained through a formal definition.

1.4.4 Deductive - This class of modules contains formal proofs of theorems associated with a given concept. They deal only with deductive formal proofs and not with inductive, empirical verifications. The central concept of such a module is the name or description of a theorem.

1.4.5 Problems - This is a class of module which contains problems to be solved by the student.

1.4.6 Examples and Exercises - This is a group of modules that contains (worked out) demonstrations and exercises.

1.4.7 Conjectives and Hypotheses - This class of modules contains unproven theorems and hypotheses open to testing.

Given the stated classification of modules, when different modes of presentation are referred to, the utilization in the presentation of the different types or combination of types of modules is intended.

Q12 Retrieve (Q1) in a non-definitional illustrative explication mode for g. (Note that this request corresponds to task No. 3 of the part of the previous report entitled Task Possibilities)

Q13 Retrieve (Q1) in 1.4.2, a non-definitional illustrative explication mode followed by 1.4.3, a formal definition and 1.4.4, relevant theorem.

Q14 Given (Q6) or (Q8) or (Q11), utilize mode of presentation

2. The Structure of A Question

2.1 Basic Assumptions and Rules

In order to make the distinctions between unique questions over the same task more easily identifiable, a more precise description of the structure of a question is needed. The following are basic assumptions and rules associated with the generating of a representational structure for a request.

2.1.1 A module is a unit of material relevant to a a given subject with which is associated a term T, to be explained, and a set of other terms that are necessary to explaining T_1.

2.1.2 Call each module a node on a tree-graph.

2.1.3 If, in building the structure of a request, a term node has not been previously named, then it is designated a continuing node, and is represented graphically (x) such that x is the name of the node.

2.1.4 If a node-term has been previously named, then it is designated a terminating node, and given the graphic representation $\boxed{x}$. Also, a node is designated terminating if excluded by request; e.g. see [1.1 (Q2)].

2.1.5 Call the naming of a node an event $t = \{f_0, f, \ldots, f_n\}$ such that f_n is the last node in the order of naming.

2.1.6 If a node has been designated as continuing with event f_n, then its extensional term nodes are named in the order of occurence of events. Hence the extensional nodes of f_{r-1} will have to be named before naming the extensional nodes with event f_r.

2.1.7 A term-node is extensional whenever it is used to explain or is associated with the term of another node. Extensional nodes derive only from continuing ones.

Given the request: Retrieve a subcourse on Eulerian graphs for a naive learner, utilizing the above assumption and rules.

First, all of the terms necessary for explaining Euler graphs are identified. This in turn leads to the identification of all the terms necessary to explain the terms used in explaining Euler graphs. This process continues until every necessary term has been named. The structure is said to be complete when every term has been named and every node has become terminal.

<u>Concept Number Association</u>

1.	Eulerian Graph	⟶	connected graph, graph, closed path, path, edge, Eulerian path	2, 3, 4, 5, 6, 7
2.	converted graph	⟶	vertex, chain	8, 9
3.	graph	⟶	vertex, edge	8, 6
4.	closed path	⟶	chain, initial vertex, final vertex	9, 10, 11
5.	path	⟶	edge, edge-sequence	6, 12
6.	edge	⟶	graph	3
7.	Eulerian path	⟶	path, closed path, edge	5, 4, 6
8.	vertex	⟶	graph	3
9.	chain	⟶	edge-sequence, edge, path, vertex	12, 6, 5, 8
10.	initial vertex	⟶	vertex, edge-sequence	8, 12
11.	final vertex	⟶	vertex, edge-sequence	8, 12
12.	edge-sequence	⟶	edge, graph	6, 3

Number-naming

1 ——————> 2, 3, 4, 5, 6, 7

2 ——————> 8, 9

3 ——————> 8, 6

4 ——————> 9, 10, 11

5 ——————> 6, 12

6 ——————> 3

7 ——————> 5, 4, 6

8 ——————> 3

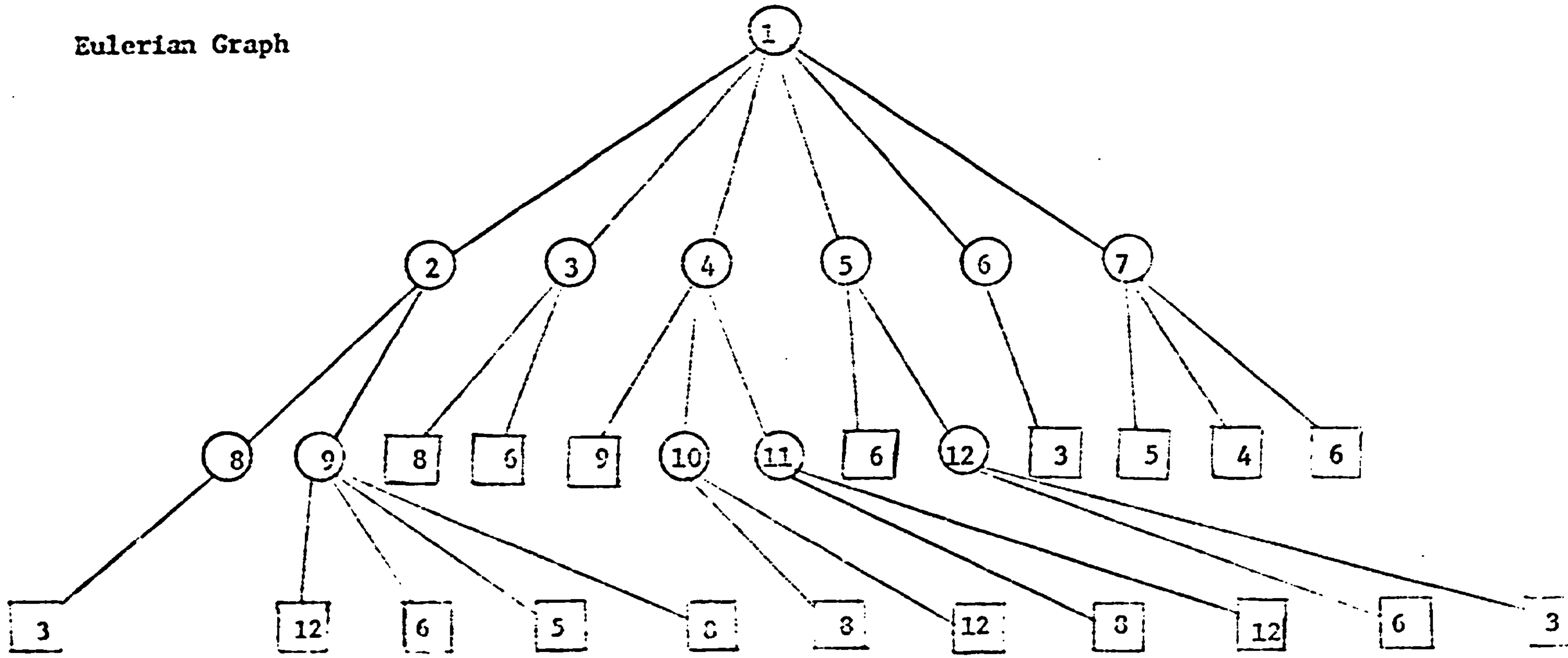
9 ——————> 12, 6, 5, 8

10 ——————> 8, 12

11 ——————> 8, 12

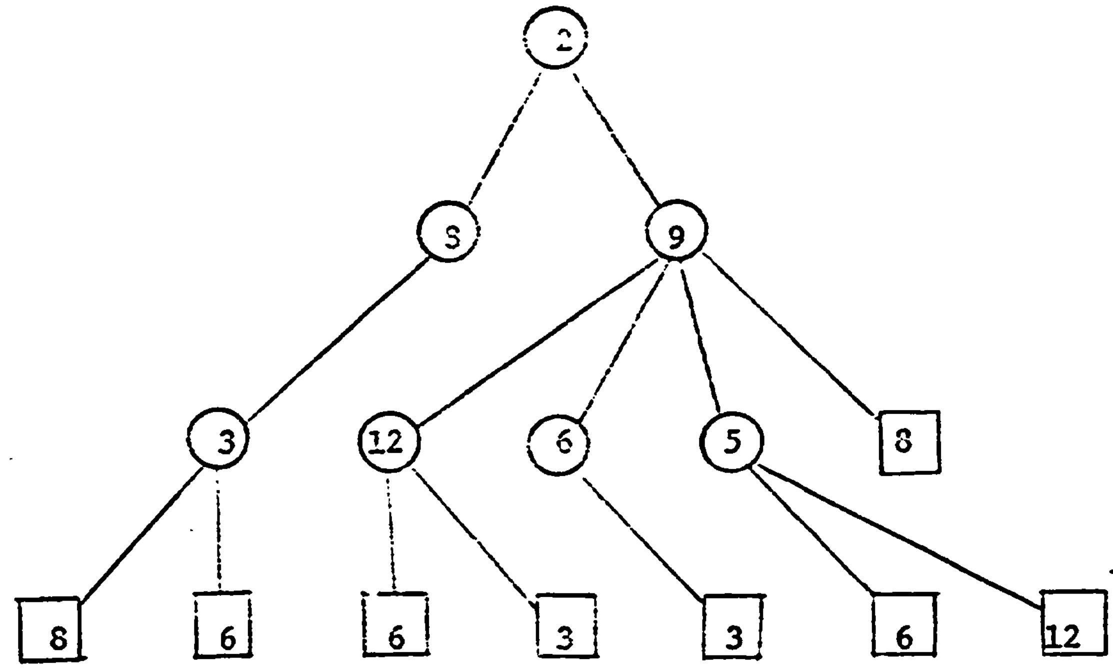
12 ——————> 6, 3

Eulerian Graph



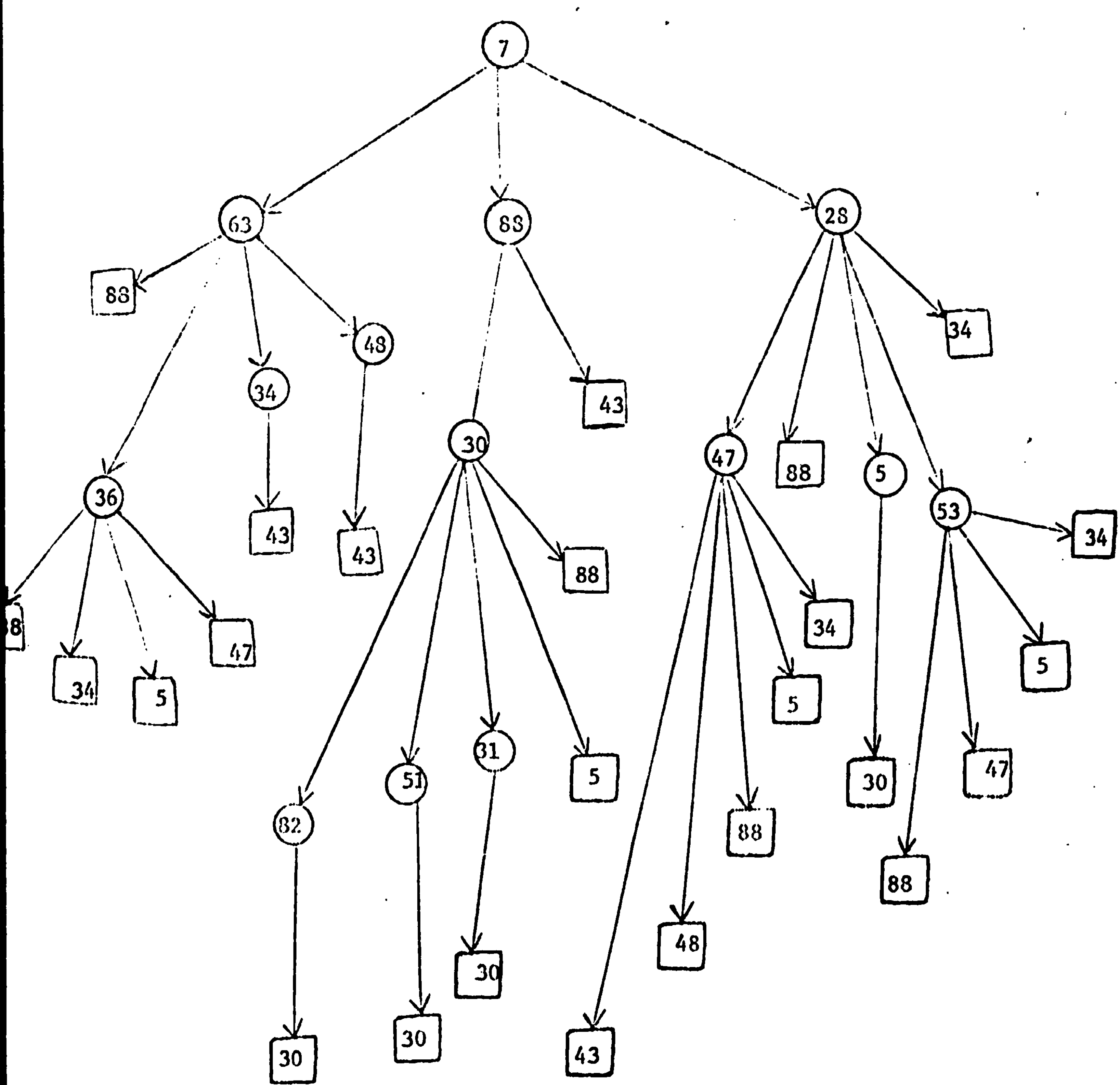
The structure of the query:

"Retrieve a sub-course on Eulerian graphs."



The structure of the query:

"Retrieve a subcourse on connected graphs."



This is a structure of the same query on Euler graphs using a different author's interpretation.

Request: Retrieve a subcourse on a term a in class A terms. Let $\underline{a} = \{\underline{a}_1\ \underline{a}_2 \ldots a_n\}$ such that n is the number of module class A terms necessary to retrieve a subcourse on a.

SYSTEM'S TASK

Step 1: Parse request: If definitional module mobiles (DMP) are not excluded by request, go to Step 2. If DMP are excluded by request, go to Step 7.

Step 2: Scan DMP for a: If DMP for a does not exist go to Step 7. If DMP for a exists, create a node for it, name it a and go to Step 3.

Step 3: Identify from DMP for a class B terms that are associated with a and list them alphabetically: Go to Subroutine 1.

Subroutine 1.

Create a node extended from node a (extensional node) for the first term in the alphabetical list of identified class B terms and name it by name of term. Scan previously named nodes. If node has been previously named (or if name of its term was excluded by request), designate it terminating. If it had not been previously named (and/or not excluded by request), designate it continuing. Repeat this operation on each of the remaining alphabetically ordered terms of class B that are associated with DMP for a. After operation is completed on the last class B term in the alphabetical list, go to Step 4.

Step 4: Identify all remaining continuing nodes. If no continuing nodes exist, go to Step 5. If continuing nodes exist, select the earliest named one in the order of naming and go to Subroutine 2.

Subroutine 2:

Apply Step 1 to selected node. Repeat operation until all named nodes are designated terminating, then end tree and go to Step 5.

Step 5: Identify the last named continuing node whose module has not been retrieved. If such a node does not exist stop. If it does exists, go to Step 6.

Step 6: Retrieve DMP for identified node (call it a) and go to Step 7.

Step 7: Parse request: If illustrative explication module profiles (IEMP) are not excluded by request, go to Step 8. If IEMP are excluded by request, go to Step 10.

Step 8: Scan IEMP for a. If IEMP for a does not exist, go to Step 10. If IEMP for a exists, go to Step 9.

Step 9: Retrieve IEMP for a and go to Step 10.

Step 10: Parse request: If theorem module profiles (TMP) are not excluded by request, go to Step 11. If TMP are excluded by request, go to Step 13.

Step 11: Scan TMP for a. If TMP for a does not exist, go to Step 13. If TMP for a exists, go to Step 12.

Step 12: Retrieve TMP for a and go to Step 13.

Step 13: Parse request: If problem module profile (PMP) are not excluded by request, go to Step 14. If PMP are excluded by request go to Step 5.

Step 14: Scan PMP for a. If PMP for a does not exist, go to Step 5. If PMP for a exists, go to Step 15.

Step 15: Retrieve PMP for a and go to Step 5.

Addendum to Sequence of Steps

A primitive is defined as a term a: When a is defined, it uses at least one term b, and when b is defined, it uses at least term a.

Before retrieving definitional modules as outlined in Steps 1 - 10, identify all continuing nodes whose terms are primitive. Then retrieve DMP, IEMP, TMP, and PMP, whenever existing. After finishing this process go to Step 5.

Example of the Systems Response to a Query

Request: Retrieve a subcourse on Eulerian graphs with multiple examples and theorems whenever available, but no problems.

A graph is defined to be a pair V(G), E(G), where V(G) is a non-empty finite set of elements called vertices, and E(G) is a finite family of unordered pairs of (not necessarily distinct) elements of V(G) called edges; note that the use of the word 'family' permits the existence of multiple edges. We shall call V(G) the vertex-set and E(G) the edge-family of G.

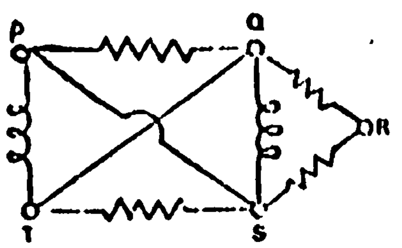
A	B	C	WIL/1/14
graph	non-empty finite set		
	element	F	1
	vertex		
	unordered pairs	H	1
	edge		
	family	D	1
	multiple edges		
	vertex-set		
	edge-family		

Fig. 17

Consider Figs. 1 and 2 which depict, respectively, part of an electrical network and part of a road map. It is clear that either of them can be represented diagrammatically by means of points and lines as in Fig. 3. The points P, Q, R, S, and T are called vertices and the lines are called edges; the whole diagram is called a graph. (Note that the intersection of the lines PS and QT is not a vertex of the graph since it does not correspond to the meeting of two wires or to a cross-roads).

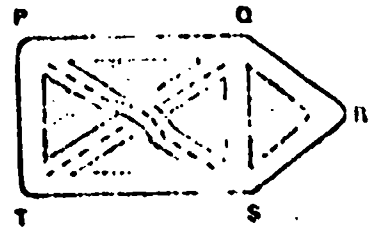
A	B	C	WIL/1/2
graph	electrical network road map	F	1
	point line	H	2
	vertex edge	D	1

Fig. 18



A	B	C	WIL/1/3
graph	electrical network		
		F	2
		H	6
		D	1

Fig. 19



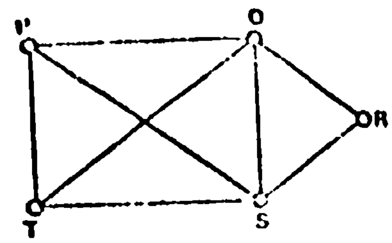
A	B	C	WIL/1/4
graph	road map road intersection	F	2
		H	7
		D	1

Fig. 20

Clearly the graph in WIL/1/6 can also represent other situations. For example, if P, Q, R, S and T represent football teams, then the existence of an edge might correspond to the playing of a game between the teams at its endpoints (so that in Fig. 3, P has played against S but not against R); in this case, the degree of a vertex is the number of games played by the corresponding team.

A	B	C	WIL/1/5
graph	football edge game team endpoints degree vertex	F	1
		H	2
		D	1

Fig. 21



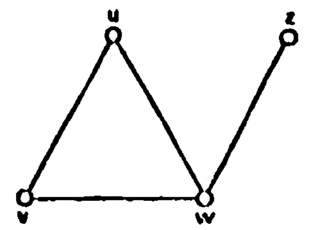
A	B	C	WIL/1/6
graph	football edge	F	2
	game end point	H	7
	degree of a vertex	D	1

Fig. 22

WIL/1/16 represents the simple graph G whose vertex-set V(G) is the set {u,v,w,z}, and whose edge-set E(G) consists of the pairs {u,v}, {v,w}, {u,w} and {w,z}. The edge {v,w} is said to join the vertices v and w; note that since E(G) is a set, rather than a family, there can never be more than one edge joining a given pair of vertices of a simple graph.

A	B	C	WIL/1/7
simple graph	vertex-set edge-set	F	1
	pair edge	H	2
	vertex set family	D	1

Fig. 23



A	B	C	WIL/1/8
simple graph	vertex-set		
	edge-set	F	2
	pair		
	edge	H	7
	vertex		
	set	D	1
	family		

Fig. 24

Given any graph G, an edge-sequence in G is finite sequence of edges of the form

$$\{v_0,v_1\}, \{v_1,v_2\}, \ldots, \{v_{m-1}, v_m\}$$

(also denoted by $v_0 \longrightarrow v_1 \longrightarrow v_2 \longrightarrow \ldots \longrightarrow v_m$). It is clear that an edge-sequence has the property that any two consecutive edges are either adjacent or identical; however, an arbitrary sequence of edges of G which has this property is not necessarily an edge-sequence.

A	B	C	WIL/1/9
edge-sequence	finite sequence		
	edge	F	1
	form		
	consecutive edges	H	1
	adjacent edges		
	identical edges	D	1
	arbitrary sequence		

Fig. 25

An edge-sequence appears in the literature as a walk, route, path or edge-progression

A	B		
edge-sequence	walk route path edge-progression	C	WIL/1/10
		F	1
		H	1
		D	2

Fig. 26

An edge-sequence trivally determines a sequence of vertices $v_0, v_1, \ldots, v_m$; we call v_0 the initial vertex and v_m the final vertex of the edge-sequence, and speak of an edge-sequence from v_0 to v_m.

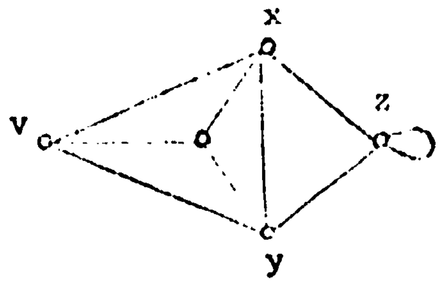
A	B		
edge-sequence	sequence of vertices initial vertex final vertex	C	WIL/1/11
		F	1
		H	2
		D	1

Fig. 27

An edge-sequence in which all the edges and vertices $v_0, v_1, \ldots v_m$ are distinct is called a chain.

A	B		
chain	edge-sequence edge vertex	C	WIL/1/12
		F	1
		H	1
		D	2

Fig. 28



v w x y z is a chain

A	B	C	WIL/1/13
chain	edge-sequence edge vertex	F	2
		H	7
		D	1

Fig. 29

Eulerian path is a closed path which includes every edge of G.

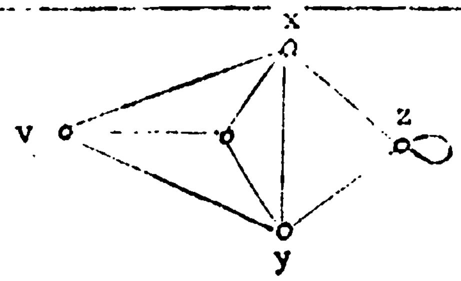
A	B	C	WIL/1/14
Eulerian path	closed path	F	1
	edge	H	1
		D	1

Fig. 30

A graph where all the edges (but not necessarily the vertices) are distinct is called a path.

A	B	C	WIL/1/15
path	graph edge distinct	F	1
		H	1
		D	1

Fig. 31



v → w → x → y → z → z → x is a path

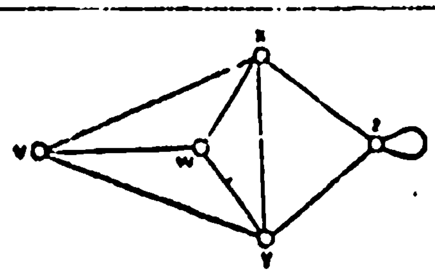
A	B	C WIL/1/16
path	graph edge distinct edge	F 2 H 7 D 1

Fig. 32

A path is closed if V_0, the initial vertex is equal to V_M, the final vertex.

A	B	C WIL/1/17
closed path	vertex initial vertex final vertex	F 1 H 1 D 1

Fig. 33



v → w → x → y → z → x → v is a closed path

A	B	C WIL/1/18
closed path	vertex initial vertex final vertex	F 2 H 7 D 1

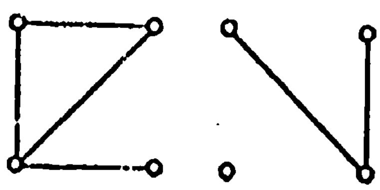
Fig. 34

A graph G is said to be connected if given any pair of vertices v, w, of G, there is a chain from v to w.

A	B	C	WIL/1/19
connected graph	pair of vertices chain	F	1
		H	1
		D	1

Fig. 35

A connected graph with three components is shown in WIL/1/20.



A	B	C	WIL/1/20
connected graph	pair of vertices chain	F	2
		H	7
		D	1

Fig. 36

A graph is connected in the above sense if and only if it is connected in the sense of 3.

Proof. $\Longrightarrow$ Let G be a graph which is connected in the above sense. If G is the union of two (disjoint) subgraphs, and v and w are two vertices, one from each subgraph, then any chain from v to w must contain an edge which is incident to a vertex of each subgraph: since no such edge exists, we have a contradiction.

Now suppose that G is connected in the sense of 3, and suppose that there is no chain connecting a given pair of vertices v and w; if we define connected components as above, then v and w will lie in different components. We can then express G as the union of two graphs, one which is the component containing v and the other of which is the union of the remaining components; this establishes the required contradiction.

Now that we know what connectedness means, it is natural to try to find out something about connected graphs. One direction of interest is to investigate bounds for the number of edges of a simple graph on n vertices with a given number of components. If such a graph is connected, it seems reasonable to expect that the graph has fewest edges when it has no circuits -- such a graph is called a tree -- and most edges when it is a complete graph; this would imply that the number of edges must lie between $n - 1$ and $\frac{1}{2}n(n-1)$. We shall, in fact, prove a stronger theorem which includes this result as a special case.

<u>A</u>	<u>B</u>	<u>C</u>	WIL/1/21
connected graph	union disjoint graphs	<u>F</u>	1
	veitex subgraph	<u>H</u>	3
	chain edge	<u>D</u>	1
	connected components union		

Fig. 37

Let G be a simple graph on n vertices; if G has k components, then the number m of edges of G satisfies

$$n-K \leqq m \leqq \tfrac{1}{2}(n-k)(n-k+1).$$

Proof. To prove that $m \leqq n-k$, we use induction on the number of edges of G, the result being trivial if G is a null graph. If G contains as few edges as possible (say m_0), then the removal of any edge of G must increase the number of components by one, and the graph which remains will have n vertices, k + 1 components, and $m_0 - 1$ edges. It follows from induction hypothesis that $m_0 - 1 \geqq n - (k+1)$, from which we immediately deduce that $m_0 \geqq n - k$, as required.

To prove the upper bound, we can assume that each component of G is a complete graph. Suppose, then that there are two components C_i and C_j with n_i and n_j vertices respectively, where $n_i \geqq n_j > 1$. If we replace C_i and C_j by complete graphs on $n_i + 1$ and $n_j - 1$ vertices, then the total number of vertices remains unchanged, and the number of edges is increased by

$$\tfrac{1}{2}\{(n_i + 1)n_i - n_i(n_i - 1)\} - \tfrac{1}{2}\{n_j(n_j - 1) - (n_j - 1)(n_j - 2)\} = n_i - n_j + 1,$$

which is positive. It follows that in order to attain the maximum number of edges, G must consist of a complete graph on n-k+1 vertices and k-1 isolated vertices; the result now follows immediately.

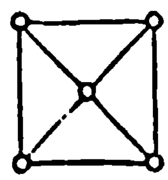
<u>A</u>	<u>B</u>	<u>C</u>	WIL/1/22
simple graph	vertex component	<u>F</u>	1
	edge null graph	<u>H</u>	3
	upper bound complete graph	<u>D</u>	1

Fig. 38

Definition: A connected graph is called Eulerian, if there exists a Eulerian path.

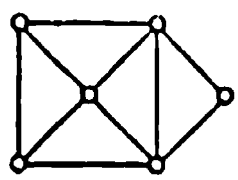
A	B	C WIL/1/22
Eulerian graph	graph connected graph Eulerian graph	F 1 H 1 D 3

Fig. 39



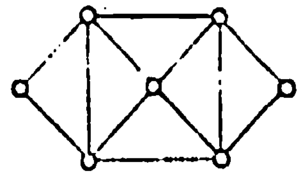
A	B	C WIL/1/23
non-Eulerian graph	connected graph closed path edge	F 2 H 7 D 1

Fig. 40



A	B	C WIL/1/24
semi-Eulerian graph	connected graph path Eulerian graph	F 2 H 7 D 1

Fig. 41



A	B	C WIL/1/25
Eulerian graph	Eulerian path connected graph	F 2
		H 7
		D 1

Fig. 42

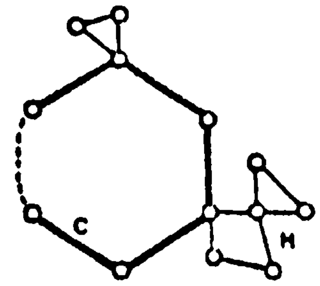
A connected graph G is Eulerian if and only if the degree of every vertex of G is even.

Proof. $\Longrightarrow$ Suppose that P is an Eulerian path of G. Whenever P passes through any vertex, there is a contribution of two towards the degree of that vertex; since every edge occurs exactly once in P, every vertex must have even degree.

$\Longleftarrow$ The proof is by induction on the number of edges of G. Since G is connected, every vertex has degree at least two, and so by the above lemma, G contains a circuit C. If C contains every edge of G, the proof is complete; if not, we remove from G the edges of C to form a new (possibly disconnected) graph H which has fewer edges than G and in which every vertex still has even degree. By the induction hypothesis, each component of H has an Eulerian path. Since each component of H has at least one vertex in common with C, by connectedness, we obtain the required Eulerian path of G by following the edges of C until a non-isolated vertex of H is reached, tracing the Eulerian path of the component of H which contains that vertex, and then continuing along the edges of C until we reach a vertex belonging to another component of H, and so on; the whole process terminates when we get back to the initial vertex (see WIL/1/27.)

A	B	C WIL/1/26
Eulerian graph	connected graph degree vertex Eulerian path edge connectedness	F 1 H 3 D 1

Fig. 43



A	B		
		C	WIL/1/26
Eulerian graph	connected graph degree	F	1
	vertex Eulerian path	H	3
	edge connectedness	D	1

Fig. 44

Let G be an Eulerian graph; then the following construction is always possible, and produces an Eulerian path of G. Start at any vertex u and traverse the edges in an arbitrary manner, subject only to the following rules:

(i) erase the edges as they are traversed, and if any isolated vertices result erase them too; (ii) at each stage, use an isthmus only if there is no alternative.

Proof. We shall show first that at each stage the construction may be carried out. Suppose that we have just reached a vertex v; then if v ≠ u, the subgraph H which still remains is connected and contains only two vertices of odd degree -- namely, u and v. By corollary 6D, H contains a semi-Eulerian path P from v to u. Since the removal of the first edge of P does not disconnect H, if follows that at each stage the construction is possible. If v = u, the proof is almost identical, as long as there are still edges incident with u.

It remains only to show that the construction always yields a complete Eulerian path. But this is clear, since there can be no edges of G remaining untraversed when the last edge incident to u is used (since otherwise the removal of some earlier edge adjacent to one of these edges would have disconnected the graph.)

A	B		
		C	WIL/1/28
Eulerian graph	Eulerian path vertex	F	1
	edge isthmus	H	3
		D	1

APPENDIX

orgia
titute
chnology SCHOOL OF INFORMATION AND COMPUTER SCIENCE / (404) 894-3152 / ATLANTA, GEORGIA 30332

March 7, 1974

We would like to solicit your help in compiling some data that will be used in a research project that is currently underway at Georgia Institute of Technology.

STITE (Scientific and Technical Information Transfer for Education) is an NSF sponsored project, the objective of which is to enhance the use of science and technical information systems by educators.

One result of research and development in the field of science information in recent years has been the establishment of large banks of descriptive information and bibliographic data that is stored on digital and analog media. These collections of data, along with the mechanisms for their organization, search, and dissemination, comprise science and technical information systems: examples of such centers would be the Chemical Abstracts Service of the American Chemical Society, NASA Scientific and Technical Information Facility, The Information Section of Wyeth Laboratories, the North Carolina Science and Technology Research Center, and so forth.

The utilization of these centers has, in the past, been primarily by research facilities and by industry. However, the use of resources so valuable should be extended, and the field o feducation, especially in science and engineering, seems to be a natural direction to take.

Therefore, the goals of STITE include the following:

1. To describe operationally the process of transformation of scientific and technical information system outputs for the purpose of integrating them into the content of science learning systems (i.e. computer-based as well as routine class-room type educational systems).

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March 7, 1974

2. To investigate to what extent and to what specific purposes educators are making use of information available from scientific and technical information systems and what factors could enhance their utilization of these systems.

3. To investigate comparatively the design and operating characteristics of scientific and technical information systems and science learning systems, particularly from the viewpoint of requirements for transferring information between them via a man-machine interface.

4. To implement an experimental design of a limited transfer mechanism from appropriate existing science information systems into science learning systems and to evaluate the cost effectiveness of that mechanism.

Enclosed you will find a questionnaire the answers to which should provide facts which are essential for our work. Please take a few minutes of your time to complete it and return it in the enclosed, stamped envelope.

The success of this study will depend upon your cooperation, and we are grateful for your assistance.

Sincerely yours,

Pranas Zunde
Professor,
School of Information and Computer Science

Enclosures (2)

PZ:jbo

ia Institute of Technology, School of Information & Computer Science, Atlanta, Ga. 30332

SURVEY OF INFORMATION NEEDS OF EDUCATORS

1. Are you familiar with the services offered by any of the scientific and technical information systems?

   YES ____ (If yes, please identify which system(s) you are familiar with:

   ____

   ____

   ____

   NO ____ (If no, please go to question No. 10.)

2. Have you ever used any of the services provided by any of the scientific and technical information systems?

   YES ____ (If yes, please identify the system(s) you have used.

   ____

   ____

   ____

   NO ____ (If no, please specify the reasons for not using the service.

   ____

   ____

   ____

   Please answer questions 9, 10 and 11)

a) What kind of services and/or materials have you requested from scientific and technical information systems?

   Monographs ____

   Copies of articles ____

   Patents ____

   Data ____

   Abstracts of documents ____

   Bibliographic compilations ____

   Literature searches ____

   On-line browsing ____

   Translation of documents ____

   Other (Please specify) ____

b) Did you obtain the information you requested?

Never ____
Sometimes ____
Often ____
Always ____

c) Were you satisfied with the services of the scientific and technical information systems?

Never ____
Sometimes ____
Often ____
Always ____

4. Did you request and receive information directly from the scientific and technical information systems or through some other channels (e.g. library, etc.)

Direct ____
Other channels (Please specify) ____________________

5. For what purposes have you used the services of scientific and technical information systems?

Research ____
Teaching ____
Others (Please specify) ____________________

If you have checked "teaching" please go to next question. If you have not checked "teaching" go to question No. 10.

6. Please specify courses for which you have used scientific and technical information system services in the last two years.

Course Title	Level of Difficulty		Type	
1) ____________	Introductory	____	Lecture	____
	Intermediate	____	Seminar	____
	Advanced	____	Project	____
			Laboratory	____

(continued)

6. (continued)

Course Title	Level of Difficulty		Type	
2) ______________	Introductory	____	Lecture	____
	Intermediate	____	Seminar	____
	Advanced	____	Project	____
			Laboratory	____
3) ______________	Introductory	____	Lecture	____
	Intermediate	____	Seminar	____
	Advanced	____	Project	____
			Laboratory	____

(If you need more space, use the back of this sheet.)

7. For what specific teaching purposes did you use scientific and technical information system services?

   - Development of a new course ____
   - Updating course materials ____
   - Preparation of illustrative examples ____
   - Preparation of problems and exercises ____
   - Selection of case studies ____
   - Preparation of state-of-the-art reviews ____
   - Compilation of bibliographic references ____
   - Collection of data ____
   - Preparation of quizzes and/or tests ____
   - Assisting students in homework assignments ____
   - Compilation of bibliographic references ____
   - Current awareness in course subject area ____

8. How many times did you use scientific and technical information system services for teaching purposes during the last two years?

   - Once ____
   - 1 to 5 times ____
   - 6 to 20 times ____
   - More than 20 times ____

9. In your opinion, what features relating to types of materials, ease of access, manipulation, etc. would make the utilization of the resources of scientific and technical information systems for teaching purposes more attractive?

____

____

____

____

____

____

10. Have you used any technology-based teaching systems, such as CAI, in teaching any of your courses?

YES ____ (If yes, please name the systems. ______________

____

____

____

____.)

NO ____

11. If you have used technology-based systems, do you feel that information needs for the preparation of these types of courses are different than those of other types?

YES ____ (If yes, please explain. ______________

____

____

____

____

____

____

____.)

NO ____

C. LETTER TO INFORMATION CENTERS

orgia
titute
chnology SCHOOL OF INFORMATION AND COMPUTER SCIENCE / (404) 894-3152 / ATLANTA, GEORGIA 30332

March 25, 1974

Dear Sir:

Under an NSF grant, we are currently working on a research project here at Georgia Institute of Technology involving the transfer of scientific and technical information from its present repositories into learning systems for the specific needs of the educator community (i.e., professors, teachers, curriculum planners, materials specialists, etc.) Within the general objective of enhancing the use of science information systems by educators are the following specific and related goals:

1. To describe operationally the process of the transformation of scientific and technical information system outputs for the purpose of integrating them into the content of science learning systems (i.e., computer-based as well as routine class-room type educational systems)

2. To investigate to what extent and for what specific purposes educators are making use of information available from scientific and technical information systems and what factors could enhance their utilization of these systems.

3. To investigate comparatively the design and operating characteristics of scientific and technical information systems and science learning systems, particularly from the viewpoint of requirements for transferring information between them via a man-machine interface.

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March 25, 1974

4. To implement an experimental design of a limited transfer mechanism from appropriate existing science information systems into science learning systems and to evaluate the cost effectiveness of that mechanism.

As we attempt to answer the question of the present usage of information centers by educators, it would be helpful to know if any such studies have been conducted in your center and, if so, where and how the results of these studies can be obtained. We would be also interested to know whether you possess any kind of records which, when analyzed, would reveal information about the use of your center by educators, and, if so, whether you could make those records available to us.

If you wish additional information concerning our inquiry, please feel free to telephone me collect at (404) 894-4671.

Thank you in advance for your cooperation.

Sincerely yours,

Pranas Zunde
Professor, ICS

PZ:jbo

D. LIST OF CENTERS RECEIVING

UTILIZATION INQUIRY

American Chemical Society
University Post Office
Columbus, Ohio 43210

American Geological Institute
2201 M. Street, North West
Washington, D. C. 20037

American Institute of Aeronautics and Astronautics (AIAA)
750 Third Avenue
New York, New York 10017

American Institute of Physics (AIP)
335 East 45th Street
New York, New York 10017

American Library Association (ALA)
50 East Huron Street
Chicago, Illinois 60611

American Mathematical Society (AMS)
321 South Main Street
P.O. Box 6248
Providence, Rhode Island 02904

American Medical Association (AMA)
535 North Dearborn Street
Chicago, Illinois 60614

American Petroleum Institute (API)
1271 Avenue of the Americas
New York, New York 10020

American Society for Metals (A M)
Metals Park, Ohio 44073

American Society Hospital Pharmacists (ASHP)
4630 Montgomery Avenue
Washington, D. C. 20014

Atomics International Liquid Metals Information Center (LMIC)
P.O. Box 1449
Canoga Park, California 91304

Battelle Memorial Institute - Columbus Laboratories (BMI)
505 King Avenue
Columbus, Ohio 43201

Becker and Hayes, Inc. (B&H)
6400 Goldsboro Road
thesda, Maryland 20034

Belfour Stulen, Inc., Mechanical Properties Data Center (MPDC)
13919 West Bay Shore Drive
Traverse City, Michigan 49684

Biosciences Information Service of Biological Abstracts (BIOSIS)
2100 Arch Street
Philadelphia, Pennsylvania 19103

Brigham Young University
574 JRCL
Provo, Utah 84601

Center for Applied Linguistics (CAL)
1717 Massachusetts Avenue, North West
Washington, D.C. 20036

Chemical Horizons, Inc.
274 Madison Avenue
New York, New York 10016

Chemical Systems, Inc., Computerized Structural Group Index of Commerical Organic Chemicals
P.O. Box 5523, Southfield Station
Shreveport, Louisiana 71105

Climax Molylodenum Company
Technical Information Center
1270 Avenue of the Americas
New York, New York 10020

College of Physicians
Medical Documentation Service (MDS)
19 South 22nd Street
Philadelphia, Pennsylvania 19103

Computing and Software, Inc., Derivation and Tabulation Associates, Inc. (D.A.T.A.)
32 Lincoln Avenue
Orange, New Jersey 07050

John Crerar Library
National Translations Center (NTC)
35 West 33rd Street
Chicago, Illinois 60616

Dittberner Associates
Project Master
4900 Auburn Avenue
Bethesda, Maryland 20014

Dow Chemical Company
Joint Army-Navy-Air Force Thermochemical Tables (JANAF)
Thermal Research Laboratory, 1707 Building
Midland, Michigan 48640

Excerpta Medica Information Systems, Inc.
228 Alexander Street
Princeton, New Jersey 08540

Franklin Institute Research Laboratories, Science Information Services Department (SIS)
20th and Benjamin Franklin Parkway
Philadelphia, Pennsylvania 19103

General Telephone and Electronics Laboratories
Technical Information Program
208-20 Willets Point Boulevard
Bayside, New York 11360

George Washington University Department of Medical & Public Affairs (BSCP)
2001 South Street North West
Washington, D.C. 20009

Honeywell Information Systems, Inc. (HISI)
2701 Fourth Avenue South
Minneapolis, Minnesota 55408

Illinois Institute of Technology (LLT)
IIT Research Institute (IITRI)
Binary Metal and Metalloid Constitution Data Center
10 West 35th Street
Chicago, Illinois 60616

Institute for Scientific Information (ISI)
325 Chestnut Street
Philadelphia, Pennsylvania 19106

Institute of Electrical and Electronics Engineers (IEEE)
Information Services Department
345 East 47th Street
New York, New York 10017

Institute of Paper Chemistry
Division of Industrial and Environmental Systems (IES)
1043 East South River Street
Appleton, Wisconsin 54911

Institute of Textile Technology Textile Information Center
Route 250 West
Charlottesville, Virginia 22902

Interdok Corporation
173 Halstead Avenue
Harrison, New York 10528

Iowa State University
Institute for Atomic Research
Rare-Earth Information Center (RIC)
Ames, Iowa 50010

Lockheed Aircraft Corporation, Lockheed-Georgia Company, Scientific & Technical Information Department (SCI-TECH)
South Cobb Drive
Marietta, Georgia 30060

North Carolina Board of Science and Technology
Science & Technology Research Center (STRC)
P.O. Box 12234
Research Triangle Park, North Carolina 27709

Ocean Engineering Information Service
P.O. Box 989
LaJolla, California 92037

Ohio State University Libraries
Mechanized Information Center (MIC)
1858 Neil Avenue
Columbus, Ohio 43210

Oklahoma State Department of Libraries MARC Services
109 State Capitol
Oklahoma City, Oklahoma 73105

Purdue University
Thermophysical Properties Research Center (TPRC)
2595 Yeager Road
West Lafayette, Indiana 47906

U.S. Air Force
Air Force Materials Laboratory (AFML)
Aerospace Materials Information Center (AMIC)
Wright-Patterson Air Force Base, Ohio 45433

U.S. Atomic Energy Commission
Ames Laboratory
Ames Selective Dissemination of Information Computer System
Iowa State University
Ames, Iowa 50010

U.S. Atomic Energy Commission
Division of Technical Information Extension (DTIE)
Descriptor Indexing and Retrieval
P.O. Box 62
Oak Ridge, Tennessee 37830

U.S. Atomic Energy Commission
Oak Ridge National Laboratory (ORNL)
Computing Technology Center (CTC)
P.O. Box P
Oak Ridge, Tennessee 37830

U.S. Atomic Energy Commission
Oak Ridge National Laboratory (ORNL)
Isotopes Information Center (IIC)
P.O. Box X
Oak Ridge Tennessee 37830

U.S. Bureau of Mines
Albany Metallurgy Research Center
Thermodynamics Laboratory
Contributions to the Data on Theoretical Metallurgy
P.O. Box 70
...any, Oregon 97321

U.S. Bureau of Mines
Division of Field Operations
Alaska Field Operation Center
P.O. Box 550
Juneau, Alaska 99801

U.S. Department of Agriculture
National Agricultural Library (NAL)
U.S. Route 1
Beltsville, Maryland 20705

U.S. Enviromental Protection Agency
Air Pollution Control Office (Apco)
Office of Technical Information and Publications (OTIP)
Air Pollution Technical Information Center (APTIC)
P.O. Box 12055
Research Triangle Park, North Carolina 27709

U.S. National Aeronautics and Space Administration
National Space Science Data Center (NSSDC)
Code 601
Greenbelt, Maryland 20771

U.S. National Bureau of Standards
Cryogenic Data Center
Boulder, Colorado 80302

U.S. National Bureau of Standards
Office of Engineering Standards Services
Information Section
Room B 147, Technology Building
Quince Orchard Road and Route 70S
Gaithersburg, Maryland 20760

U.S. National Library of Medicine
8600 Rockville Pike
Bethesda, Maryland 20014

U.S. National Library of Medicine
Medical Literature Analysis and Retrieval System (MEDLARS)
8600 Rockville Pike
Bethesda, Maryland 20014

U.S. National Oceanic and Atmospheric Administration
National Ocean Survey
Lake Survey Center
Great Lakes Physical Information Analysis Center (GLPIAC)
635 Federal Building and U.S. Courthouse
Detroit, Michigan 48226

U.S. National Oceanic and Atmospheric Administration
Scientific Information and Documentation Division (SIDD)
Rockville, Maryland 20852

U. S. National Science Foundation
Office of Science Information Service (OSIS)
1800 G Street, North West
Washington, D.C. 20550

U.S. Office of Education
ERIC Clearinghouse on Educational Media and Technology
Cypress Hall-Stanford University
Stanford, California 94306

U.S. Office of Education
ERIC Clearinghouse for Linguistics (CAL/ERIC)
1717 Massachusetts Avenue, North West
Washington, D.C. 20036

U.S. Office of Education
ERIC Clearinghouse for Science and Mathematics Education (ERIC/SMAC)
Ohio State University
1460 West Lane Avenue
Columbus, Ohio 43221

U.S. Public Health Service
Bureau of Radiological Health (BRH)
Office of Information
12720 Twinbrook Parkway
Rockville, Maryland 20852

U. S. Public Health Service
National Institutes of Health
National Cancer Institute
Veterinary Medical Data Program (VMDP)
410 Wiscon Building
Bethesda, Maryland 20014

U.S. Smithsonian Institution
Science Information Exchange (SIE)
1730 M Street, North West, Room 300
Washington, D. C. 20036

University Microfilms
300 North Zeeb Road
Ann Arbor, Michigan 48106

University of Arkansas Medical Center
Department of Radiology
Diagnostic Radiology Information System (DRIS)
4301 Markham Street
Little Rock, Arkansas 72201

University of California
Lawrence Radiation Laboratory (LRL)
Thermodynamic Properties of Metals and Alloys
Hearst Mining Building
University of California, Berkeley
Berkeley, California 94720