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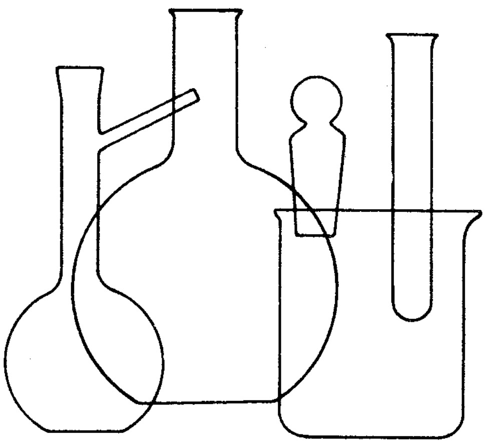

CHEMISTRY IN THE TWO-YEAR COLLEGE

VOLUME XV 1975

2YC3
COMMITTEE ON CHEMISTRY IN THE TWO-YEAR COLLEGE
DIVISION OF CHEMICAL EDUCATION • AMERICAN CHEMICAL SOCIETY

Foreword

Volume XV of Chemistry in the Two-Year College includes papers given in 1975. The remainder of the papers given at Manor Junior College under the able leadership of Mother M. Bohdonna are included. The conference editor for the Manor meeting was Howard Ayer.

The Third Canadian Conference was held in Toronto in May of 1975. Program committee chairman of the Canadian Region was Graeme Welch from John Abbott College. The members of the committee were Jans Diemer, Jim Lyons, Ivan Bastien, C. Patel and Ken Taylor. The conference included a panel discussion on "Articulation: High School - College - Industry". Jans Diemer chaired this session. A symposium, "Teaching Instrumental Techniques: Allied Health Programs" was chaired by Woody Manery. Another symposium, "Computer Assisted Test Construction" was chaired by J. Colin Robertson. Doug Jardine chaired a symposium on "Approaches to General Chemistry Instruction". The final concurrent sessions were chaired by Graham Orpwood and Ken Taylor. Facilities at George Brown College of Applied Arts and Technology were very nice and members of the conference enjoyed a visit to the plastics labs on the Casa Loma Campus. Local arrangements were made by Peter Rodack of the Casa Loma Campus and his committee. Our personal thanks to Doug Jardine, who was the Conference Editor and supplied the papers to us.

The Forty-Sixth Conference was held at Clark Community College and was organized by Mabel Armstrong from Lane Community College and Jans Diemer from Camosum College. This conference was planned to allow persons from Western United States and Wastern Canada to participate. Two special sessions were on Computers in Chemistry and College Preparatory Courses. A workshop on Test Item Construction was conducted on Saturday afternoon.

Local arrangements were made by William Nelson and the Exhibit Coordinator was Peter Scott. The Conference Editor who collected these papers so they can be included in the Journal was Katherine Wissman.

Anne Minter was chairperson of the Memphis meeting and although some of these papers are in this Journal, the majority of the papers will appear in the next issue.

Jay Bardole
Editor

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COMPUTERS IN EDUCATION

CAI Without CIA

Jans Diemer
Camosun College
Victoria, British Columbia

Presented to a Special Session, "Computers in Chemistry" of the Forty-Sixth, Two Year College Chemistry Conference, Clark Community College, Vancouver, Washington, Friday, Sept. 19, 1975.

INTRODUCTION

Delivery of the lesson, now often called "learning facilitation", can only be successful when executed by an instructor (facilitator) of average to better quality. Good lesson-material organization can only come from the mind and hands of a good author.

In 1966 Silvern and Silvern outlined five major criteria which can be used to evaluate authorship. Authors should score high on:

- job and task analysis
- establishment of behavioral objectives
- preparation of criterion tests
- development of course outlines to the level of course-application, and
- writing of detailed lesson plans.

In the same paper the authors state that it is difficult to identify the underlying skills of each criterion. The 'phantom' like author was labeled 'instructional programmer'.

Now, about a decade later, only as few outstanding 'instructional programmers' have been identified, and educators continue to struggle with the setting of measurable, pedagogically acceptable criteria and criterion-tests.

Impatience has overtaken many amongst our ranks. Methodology 'fads' have emerged by the handful and only a few have become accepted as valuable tools. Both good and bad authors, whether they can teach or not, have turned to computer-use and notably to the activities collectively labeled as CAI (computer assisted instruction). This unfortunate offspring of impatience is improvement of <u>instruction</u>, not <u>learning</u>. The 'workhorse'-computer has often become a convenience-tool for the instructor, and has become a source of apprehension for the student.

CAI is of little value to the student unless student needs are the center of the author's activity. The real value for the student is a summative process: instructor and CAI and student result in CAL (computer assisted learning). The three components of CAL must be further defined.

AUTHOR

A good author has the following qualities:

- is a behavioral objectives addict.
- can organize a course, modules of a course, lessons of a module, components of a lesson, and specifics of each

component in reverse order, that is to say starting with the ultimate objectives of the course and working back to the lowest level of prerequisite.

- has a reasonable affinity for the Keller-PSI plan.
- is an actor who is not going to be replaced by the computer.
- loves the student.
- does not have an affinity for computer programming.
- sees some value in logic and the scientific method(s) of problem-solving.
- is creative, and hopefully innovative.
- is willing to spend considerable amounts of time on lesson-detailing.
- wants to use the computer to enrich a course and so improve learning.

THE LEARNER (student and instructor) must also qualify. Not every student will succeed in CAL-types of experiences. Instructors do well to certain that none of the students are computophobics. In the event that students show a traumatic reaction to forced computer-use, the instructor must either remove student anxiety through appropriate activities or must offer an alternate method of achieving to the student.

The CAL-author is less likely to cause apprehension in students than the traditional CAI-type author would. The careful CAL-author will remove what I label CIA (computer induced apprehension) from peers, students and supervisors. This apprehension can be comprised of one or more of the following sensitivities (or falacies):

- technology dominates
- teachers are being replaced
- students are not treated as individuals
- machines are destructive, not instructive
- computers make mistakes

etc.

THE (AUTHOR LANGUAGE) (TOOL) must be very versatile but must never be the end to which all resources are put. A good CAL-author language will:

- support a directed dialogue between the instructor and student.
- allow for unexpected comments to be a part of every action.
- readily respond to each of a number of student actions, decisions or questions.
- not require any programming knowledge from instructor or student.
- ideally support graphics and a number of audio-visual functions.
- be easily modifiable to incorporate innovations, technical advances or pedagogical developments.
- be so versatile as to allow use by any instructor in any discipline.
- have a very simple instruction-set.

- be usable regardless of the type of terminal used by the author or student.
- allow for maximum security.
- create the basic statistical data required for evaluation of student-achievement.
- readily facilitate use by students who may have a vastly different inventory of prerequisite expertises.
- force the instructor to maintain a high level of pedagogical activity rather than allowing a recession into mechanical activities and resulting oblivion.
- support any type of activity normally associated with CAI: testing, quizzing, drilling, simulation, etc.
- allow for the use of scientific and other specific languages.

A SAMPLING OF AUTHOR-LANGUAGES

These criteria are demanding. The author language that measures up must of necessity be powerful. A number of commercial as well as custom-made author languages exist. Most of these were based on rather large computer systems: Coursewriter II and Coursewriter III, as well as TUTOR may be familiar names to you. Very recently some minicomputer producers have invested heavily in educational products, and PILOT and DECAL can be mentioned as author languages written for use on minicomputers.

With the advent of the smaller, less costly machines and very sophisticated software packages any community college can now afford at least a closer look at CAL if not implementing it in-house.

The system at Camosun is utilizing DECAL as author language, which uses BASIC as the programming language. The author language was modified slightly to make it pedagogically more acceptable to faculty. A number of instructors and instructional support staff members are now engaged in writing lesson materials to be entered into the CAL-library. Representation spans all of the College Divisions. Indeed, a flexible, open-door, Comprehensive Community College such as Camosun aims to be, can ill afford ignorance on CAL.

SOME PRACTICAL PROBLEMS

It has been said that 'punching a terminal key' is vastly different from 'delicately adjusting a stopcock'. Certainly CAL does not and shall never succeed in replacing laboratory techniques. It can only be a significant enrichment factor for the laboratory experience. Just think of the exotic chemicals, the volatile multistage reactions, or the hazardous experiments which are still considered essential to the College Curriculum. At least some of it can be simulated.

Chemical notation has been a traditional problem from which terminal designers could not escape. Only very recently a small number of 'versatile' terminals have been marketed. As a consequence very little Chemistry course material has been published in CAL-format. As a prospective CAL-author you will have little course-planning to lean on.

Systems and author languages that deviate from a standard code or programming language (and the majority of them does not presently conform to a standard of any sort) prevent an easy interchange of materials between colleges. Smaller colleges would do best to tie remotely into an existing system, or start modestly with a minisystem using a standard language such as BASIC-based PILOT or DECAL.

SOME BASIC HINTS

It takes a few individuals in a given college who are willing to sacrifice much personal time before CAL can get off the ground. Few successes were seen where entire institutions were involved in the 'GO-NOGO' decision concerning CAI-implementation. It takes some in-service training. Instructors should really qualify (be good authors) before they are allowed to use CAL. Peer-pressure is the most effective agent for the prevention of student apprehension or general system failure.

It takes a few basic skills. Probably the most valuable skill is effective flow-charting. You as participants in this conference are now invited to use the DECAL-language for the purpose of gaining some initial experiences in CAL if you never authored, or to look at a minicomputer-based CAL-system if you are not really ready to write some lesson material.

The cooperation of the Oregon Museum of Science and Industry in allowing me the use of their computer, and the assurance of Camosun's computer operations groups that our own system would be active for these exercises, is sincerely appreciated.

Individual Advisement of College Freshmen by Computers

G.A. Crosby
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Pullman, Washington 99163

Presented to a Special Session, "Computers in Chemistry", of the Forty-Sixth, Two Year College Chemistry Conference, Clark Community College, Vancouver, Washington, Friday, September 19, 1975.

Is it possible to advise students individually with such an impersonal item as the computer? At Washington State University the Department of Chemistry has been doing just that, and doing it routinely for six years.

Since 1968 we have been testing, just prior to registration, the incoming freshmen who intend to enroll in a chemistry course some time during their college careers. Our purpose is to place each student in the chemistry sequence in which he will be successful (success is defined as a final grade of C or better). We are trying to save the student time during his college career and to save money by preventing massive withdrawals from the courses.

The exam consists of four parts: (1) nine questions that quiz each student about his educational background in terms of years of algebra, chemistry, math, and other sciences already taken in high school; (2) 40 questions that test the student's knowledge of physical science with emphasis on chemistry; (3) 20 questions that measure arithmetical skills needed for problem solving in chemistry; and (4) 10 questions that assess the student's prowess in elementary math analysis. The test is multiple choice, the answers are registered on IBM score sheets, and the data are recorded on magnetic tape by a mark sense machine. The information on the magnetic tape is transferred to the IBM 360-67 computer where all grading, statistical analyses, and advising are carried out. The entire sequence from submission of the answer sheets to the mark sense machine to the final individual advisement of each student in an appropriate course sequence consumes a few hours at most. The cost per student is nominal.

The computer advises each student into one of four chemistry options; an introductory sequence that is regarded as a terminal course for nonscience majors; a standard college freshman level course required for chemistry majors and recommended or required for most science majors; and a course for the very well-prepared student, which not only satisfies science and chemistry major requirements, but saves the student valuable time in his total program. The computer also advises some students into a fourth category, NO CHEM. This advice is given to those whose test results indicate arithmetic and scientific illiteracy. For these people success in a college science course is virtually precluded.

For each student the computer produces a separate advisement sheet. This sheet contains the student's ID number, his name, his advisor's identification, the scores on the separate parts of the exam, the advice as to which course the student should take, and a set of instructions for interpreting the listed information. In addition, the student's performance on the chemistry and chemical arithmetic portions of the exam are displayed graphicallyin Figure 1. The student's performance on the math analysis portion of the exam is printed, but not graphed; this index is only used to select the well-prepared students for the highest level freshman chemistry course offered. Thus the display (figure 1) shows only the performance on the 40 chemistry and 20 arithmetic questions. The students whose scores fall into the samll area in the lower left corner are advised to take NO CHEM: those whose X falls into the block at the upper right will be advised into the standard college course <u>or</u> possibly into the course for the well prepared (if their performances on the math analysis portion are also good). The remainder are advised into the introductory sequence.

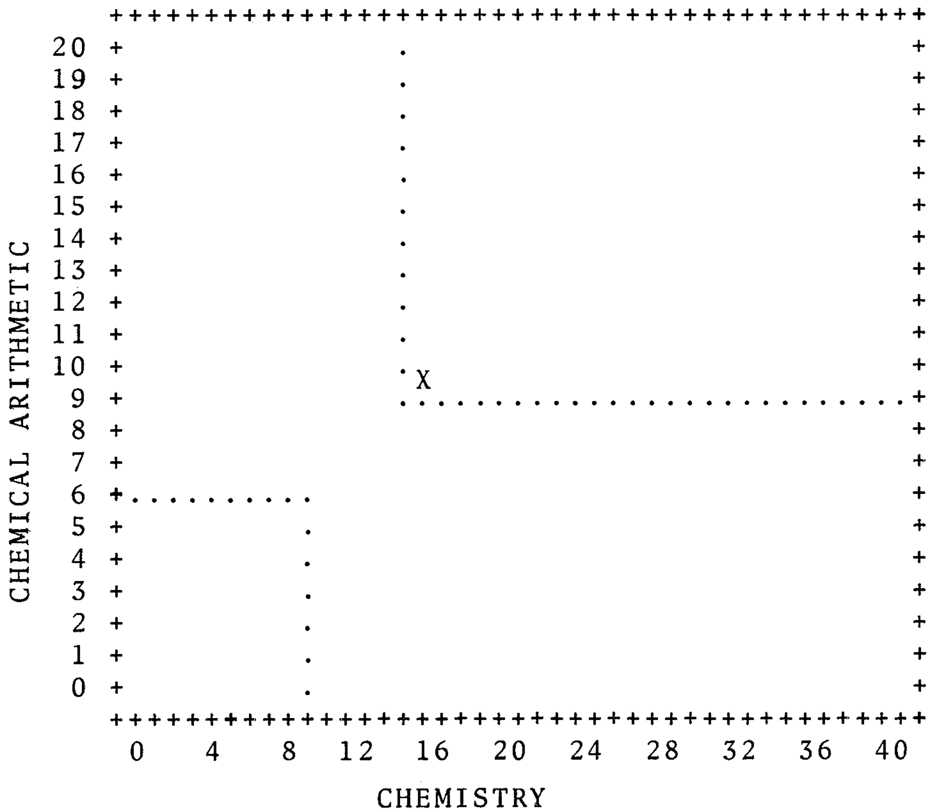

Figure 1
Graphical display of a student's performance on the chemistry and chemical arithmetic portions of the exam. The X shows that the student scored 15 in chemistry and 10 in arithmetic and marginally placed in the standard college freshman level chemistry course.

When a student meets with his advisor before registration, both can see at a glance where the student stands with respect to his peers. Borderline cases are immediately apparent, and then the goals of the student, his high school record, and his projected course load can be taken into account by the advisor before enrolling the student in one of the chemistry sequences.

We turn now to the reliability and effectiveness of the computer advisory procedure. During the last six years we have collected statistics on the test performances of over 12,000 students. We have also gathered follow-up statistics on class performances vs test scores. Statistics on students taking the exam in the Fall of 1972 will be quoted here. We followed these students for three semesters.

What we find is:

(1) Those students who do not take the advice offered and sign up for a course that is above an assessment of their capabilities fare poorly in that course. Collectively their gpa drops, and high withdrawal rates ensue. For example, of those students who were advised to take the introductory course, but registered in the standard

course, 35% were unsuccessful and received grades of D, F, W, or incomplete.

(2) Those students who sign up for a chemistry course in spite of a NO CHEM recommendation do not perform well in even the lowest level course. Records show that only the border-line performers attempt the course; of the 1972-tested group 27% were unsuccessful.

(3) Students who take the advice given by the computer receive a normal distribution of grades in the recommended courses. There are few withdrawals and incompletes and a low percentage of D's and F's. In both the introductory and standard courses success is high for those who take the advice offered; as few as 12% do not succeed (here again success is defined as a final grade of C or better).

Statistics support the success of the exam and advisement procedure in improving actual student performance in the chemistry sequences. Experience shows that most students who are advised into a particular level course by the computer enroll in that course and remain there, and the melee produced at the beginning of the term by large numbers of students changing sections is largely avoided. This is particularly important for laboratory courses, since class enrollments do not drop off and lab sections stay well occupied. Staffing laboratory sections for only a few students is expensive. Thus, a significant spinoff of the testing and computer advisement procedure is real cost effectiveness in higher education.

Although the test results have not been used for advisement in other disciplines, we have found good correlations between student performances in most introductory mathematics and physical science courses and the scores achieved on the chemistry placement examination. As expected, those skills necessary for mastering a college chemistry course are the same skills required for understanding mathematics and physics.

The test scores over the last six years, however, reveal very disconcerting trends in the quality of the preparation of incoming college students. For instance, the performance of the freshman group in 1974 on the arithmetic portion of the exam was 15% lower than that of the 1969 group, and the downward slide is continuing. This fact poses serious questions concerning the relationship of high school preparation to college success in the sciences.

In an attempt to find some answers we initiated in the spring of 1973 a small testing program in the high schools in the state of Washington.[1] Our survey of approximately 2000 students from 15 high schools shows that the courses necessary for success in the sciences in college are available in the high schools, but for numerous reasons mnay of the students are not taking them - a frightening revelation is that physics is a dying discipline in the high schools. Nevertheless, these students enter the university intending to take, for example, a course such as college chemistry without the proper background.

To remedy partially the severe problems of inadequate preparation of a large segment of students that the testing has uncovered, a remedial course, mainly in arithmetical manipulations, is being offered to those students whose career goals require the standard college course, but whose test results (and our statistical evidence) point to failure in such a course. The offering is taught mainly by lecture at present, but plans are being implemented currently to offer the course on an tutotutorial basis, since it is obvious that a university cannot afford to teach remedial courses, particularly offerings that are available in the high schools.

Our testing and advising scheme has also opened a pathway toward advanced placement. Further tests are planned to place the very well-prepared student in courses beyond the freshman-level sequences. In the proposed plan advancement will be made, however, only after thorough testing and perhaps some autotutorial work so that a student will not be accelerated beyond his capability.

For Fall 1975 the chemistry advisory exam underwent its first major revision and was extended to include all physical sciences and mathematics. The original test was modified considerably; discrimination and ease factors were calculated for each question, and poor questions were eliminated. New questions pertaining to physical sciences other than chemistry were inserted. The exam now contains 38 questions on physical sciences, 20 on arithmetical manipulations, and 12 on math. This year, new norms will be established.

On-site testing of basic skills prerequisite for success in mathematics and physical sciences courses prior to registration is feasible, inexpensive, and an effective advisement vehicle. In conjunction with other indices, such as high school transcripts and accumulated gpa's, accurate and effective advice can be offered to incoming students regarding correct course choices. The procedure saves money, especially for laboratory courses, since high dropout rates are avoided and a higher percentage of students succeed in the courses.

Supported by our studies at Washington State University in the physical sciences and the published information on downward trends in SAT scores nationwide,[2] we proffer the following analysis and suggestions. The current practices of accepting students in the university on the basis of high school gpa and even on the basis of gpa plus accumulated credits in certain core courses are not effective means for determining admissions to the university. Each year the test data show erosion of performance of incoming students in spite of a higher high school gpa. The universities are demanding higher gpa for admission and that is precisely what they are obtaining. Yet, the students are actually less qualified to succeed in college level courses. Our recommendation is to add to the current admissions criteria an additional requirement of competency based on a university-generated and university-administered examination in basic skills. With such an examination the universities could demand competence rather than grade point, and, in our opinion, implementation of such a procedure would lead eventually to a reversal of the twin ills of grade inflation and degradation of preparation that are currently eroding university standards and depreciating the value of a university education.

---

[1] J.L. Crosby and G.A. Crosby, "High School Preparation Versus College Success in the Sciences", Washington Science Teachers' Journal, 14, No. 2, 15-18 (Spring 1974). (Copies available from the authors)

[2] The Chronicle of Higher Education, XI, No. 1, 1 (Sept. 15, 1975).

Individualized Computer Generated Assignments and Tests

Ishwar Singh
Mohawk College of Applied Arts and Technology
Hamilton, Ontario

Presented to a Symposium on Computer Assisted Test Construction at the Forty-Fifth, Two Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, May 28, 1975.

In our increasing efforts to involve computers in the education of chemical engineering technology and technician students we have developed a relevant course and written various computer programs for different kinds of applications (1, 2, 3). However, one of the important applications of the computer has been its role in individualizing the educational process. To understand this let us consider the three main aims of education:

(i) to impart known skills and ideas
(ii) to help individuals synthesize ideas to obtain new skills and ideas to solve new problems
(iii) to involve individuals in ethical and behaviorial philosophy.

In order to achieve aim two, the educator must assure achievement of aim one and aim three is to be instilled along with the first two. The various computer programs that are described in this paper aid enormously in achieveing aim one and to a certain extent aim two. The role of these individualized computer generated problems (ICGP) used in an Instrumental Analysis course is illustrated in Fig. I.

The need for ICGP in teaching arises to ensure that each student is doing the necessary practice to learn the required material. When a conventional assignment is given, the students copy to various extents and this is not desirable at all. Also

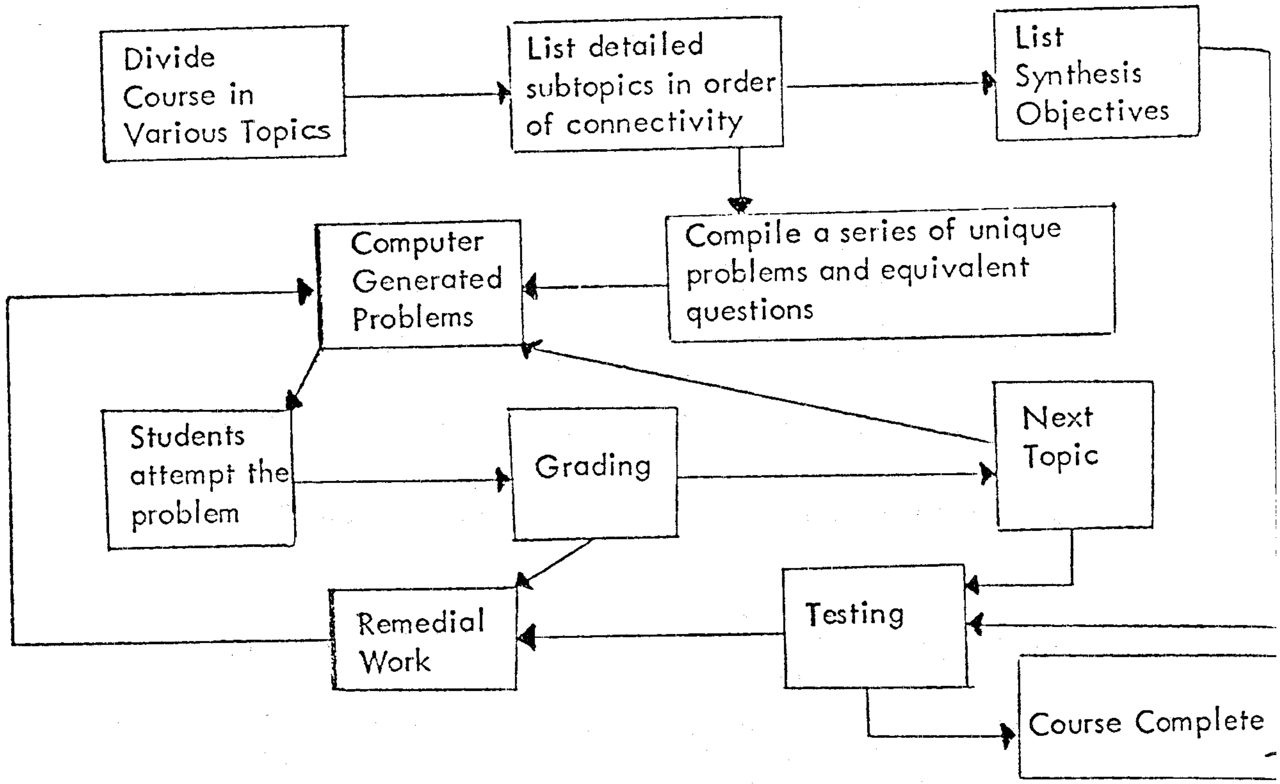

Figure I

Role of ICGP in an Instrumental Analysis Course

because of time constraints, many practical and realistic problems cannot be constructed into tests and examinations. The ICGP eliminate these enigmas to a large extent in addition to offering other advances of future applications.

ICGP Programs

At present there are thirty ICGP programs. Each program, written in FORTRAN IV, calculates and selects individual parameters for four to seven problems from a topic selected from chemical instrumentation analysis or general chemistry course. For each problem usually there are one to ten parts of computational section and in many problems logical decisions are to be made based on the computations performed. In addition to the chemistry programs we have fifteen ICGP programs covering various topics in basic Statistics, Applied Regression Analysis and first year Mathematics[4]. Since each of these programs is a separate one, the execution is fairly simple and is easily followed by using well documented procedures. Most of the programs expect an identification card, value of a variable IX, which is used as a seed value for the random number generation routine, and the names of students. After execution the computer prints one sheet for each student and at the end an answer sheet is printed for manual grading by the instructor.

A Simple Approach for Writing ICGP Programs

From our considerable experience we have simplified the procedure for writing ICGP programs. Briefly this is as follows:

(i) First a computer program for solving a problem is written

(ii) Next, the data input statements are substituted by random number generation routine

(iii) Then, print a question sheet for each student. Store the answers as subscripted variables with the subsctipt identifying the student.

(iv) Last, print one sheet at the end for the instructor with the names of students and their answers.

Random Number Generation Routine

The random numbers can be generated on any computer using various simple routines and functions available in FORTRAN IV, BASIC, APL and PL/1 languages. However there are two types of number generation that are usually required and have been most useful in our programs.

1. Uniform Numbers: To generate a number within a range, a function subprogram has been written by this author and used very extensively in ICGP programs. In fact it is this one single routine which has simplified writing of ICGP programs. To use this function subprogram, the main program should have the following statements:

```
INTEGER CALC
.
.
.
IX = 1162261467
START = CALC (IX, 2, 5)
.
.
:
```

Then suppose a user wishes to generate 100 random numbers for a dimensioned variable 'V' in a range say 29 to 99, for that the following statements should be placed after the above statements.

```
     DO  20  I = 1,100
  29 V(I) = ICALC (28,99)
```

First the main program will enter at CALC and when the statement 20 is executed as a part of the DO loop, the program enters at ICALC and bringing back with it a value between 29 to 99 and stored as V(I) in the main program. After the exit at statement 20 the numbers generated might look like this: 29.0, 55.0, 98.0, 79.0, 34.0 etc. The value of the original IX should be different to obtain different sequence of numbers each time the program is executed. This function subprogram is a modification of a subroutine given by Peterson and Holz (5) for the IBM 360/370 system of computers.

2. Normally Distributed Numbers[6]

These are numbers which tend to have a gaussian or bell shape. This type of numbers is needed for adding errors to selected parameters to give them statistical fluctuations[7]

One method to generate these numbers is a subroutine Gaus which is inefficient from a computer point of view. A more efficient method of Box and Muller[9] requires first the use of RANDU[8] to generate two uniform random numbers between 0 and 1. Then these are used to generate RN1 and RN2, the random numbers which are normally distributed with a mean of 0 and variance of 1. Randomized normal numbers are used in generating data for calibration curve, statistical testing and applied regression problems. To use this routine consider the following example of generating N replicates with a mean of 30 and standard deviation of 5. For this the following routine can be used:

```
IX1 = (a large integer number)
IX2 = (a large integer number)
DO    10 I = 1,N

GENERATE RN1 EACH TIME
BY USING CALL RANDU TO RN2

10   Y(1) = 30.0 + RN1*5.0
```

Approximately 95% of the generated data will lie between 30.0 ± 2*5.0.

Specific Examples:

The following examples show the type and nature of questions that are being used in ICGP programs.

1) In a laboratory experiment a student place ________g of iron wire in excess of HCl solution. Hydrogen gas was evolved and was collected over water in an inverted graduate. What volume of gas was collected in this way if the temperature was ____deg. Centigrade and pressure was _____ Atm.

The parameter values for the blanks in this question are calculated by the use of random number generator routine and since the gas is collected over water the vapour pressure of water has to be taken into account before the pressure for the student's problem is printed. A polynomial regression program has been used to determine the coefficients of a fifth degree polynomial relating the vapour pressure vs the temperature. The values of the coefficients are given to the program through the use of DATA statement.

2) a) Calculate the voltage of the cell made up of the pair of electrodes listed below:

A) $MA|MA^{+}(C_1M)$

B) $MB|MB^{+}(C_2M)$

b) Which electrode is +Ve
Which electrode is cathodic?
In which half-cell does oxidation occur?

What half-reaction occurs in each half-cell?

Half-Cells, MA|MA^+ and MB|MB^+ are selected at random from a choice of 30 half-cells and the concentrations are selected from 0.1 to 0.001M. Therefore each student gets two different half-cells as well as different concentrations. There is no chance for the students to copy, they must do their individual work.

In addition various other problems requiring manipulation of chemical symbols, in the form of numeric representation, logical decisions, and storage of large numbers of chemical formulae and chemical equations have been programmed as part of various ICGP programs. Multiple choice questions and questions requiring filling up of a table by interconverting certain quantities have also been programmed.

The average time that a student needs to spend on each assignment is usually two to four hours, this depending on the assignment and the individual student. In addition to forcing the students to do the regular work, the performance of students in a mathematics and an instrumental analysis course where ICGP were used seem to have improved.

Student Feed Back

The following ICGP questionnaire was distributed. Twenty-seven students responded. The questions asked were similar to the questions by Professor K. Jeffrey Johnson, of the University of Pittsburgh,[10] because of some similarities with his CGRE system.

1. Do you feel that ICGP system has helped you learn more material?

   Very definitely 13 | Doubtful 1
   Probably 14 | Definitely not 0

2. The ICGP system gave me an opportunity to demonstrate my mastery of the course material?

   Agree strongly 4 | Disagree moderately 3
   Agree moderately 21 | Disagree strongly 0

3. The ICGP system demands excess out of class time

   Agree strongly 12 | Agree moderately 11
   Disagree strongly 1 | Disagree moderately 3

4. Do you recommend that a similar system be developed wherever applicable

   Yes 25 | No 2

Test Generator System (TGS):

In addition to ICGP programs we have designed a system which will generate individual problems for a given number of students. This system can either be used for generating individual assignments or tests. Both the type and the number of questions are controlled by the instructor. This TGS system can be adopted for various other courses like Physics, Mathematics and various engineering subjects.

Multiple Choice Marking System

This system, similar to the one described by Professor Shakhashiri of the University of Wisconsin, marks multiple choice tests and keeps record of every student on the disk file. This system prints one sheet for each student containing the following information: Student's present and last score, individualized feed back for each question and a general comment based on his score in the present test.

In summary, various ICGP programs for chemical technology and technician students, a test generating system and a multiple choice marking system have been designed and written for individualizing various aspects of instruction. Our present feed back from the students is very encouraging and it is hoped that these systems will be very useful in the near future as they are extended to various courses.

Acknowledgments

Funds for writing and testing most of the ICGP programs in FORTRAN have been provided by the College Affairs Branch of the Ministry of Colleges and Universities, Government of Ontario.

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Computers Generated Problems for Chemistry Tests

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Presented to a Symposium on Computer Assisted Test Construction at the Forty-Fifth Two-Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, Canada, Jay 28, 1975.

The construction of repeatable exams is an activity in which computers have a useful role. There are several levels of sophistication possible for a computer program which generates tests. At the simplest level the program could print the desired number of randomly-ordered lists of questions and answers from an input list of questions and answers. At another level the program might involve retrieval of questions from test item banks by some pre-arranged method which selects questions according to topic, difficulty and type. In these applications, the number of items in the test item bank would limit the repeatability of the exam. The limiting size is not so much the total size of the item bank as it is the size of each subset of questions which are "equivalent" to each other. This limitation can be eliminated by having the computer program construct the questions rather than simply retrieve them.

This paper describes a system which constructs problems and answers for each test with an algorithm for each problem type. Thus, each is created as the program is executed, but never in the same way twice. Execution of this program is in the interactive mode. Requests for specific problem types are entered at a computer terminal. The results are then printed out on a high-speed printer, on standard size unlined paper, with questions on the left hand side of the paper and answers on the other side, and a code number on each side so that the question part and the answer part can be separated and later matched using the code number. The chemical symbols are in the correct format, with upper and lower case and with superscripts and subscripts.

Each problem type is stored as an algorithm for generating a test question. The algorithm includes the strings (words) which link the given data and the question. It includes the ranges in which numerical data are randomly generated, the method by which numerical data are randomly generated, the method by which some non-numerical data is constructed, and the algorithm for determining the answer. For example, a question involving an ionic compound is generated by an algorithm which (1) generates a random number between 1 and 28 for selection of the cation symbol, (2) generates a random number between the same limits for selection of the anion symbol, (3) determines how many of the chosen cation needs to be paired up with how many of the chosen anion in order to have a net charge of zero and (4) concatenates the symbols and numbers and parentheses (if needed) to construct the chemical formula, eliminating 1's where unnecessary. The chemical formula is then sent to a procedure which applies the necessary coding for superscripts and subscripts.

Some of the problem-generating algorithms are relatively simple. An example is the following:

> How many grams of [C$(N) $HOCH_2CHO$] must be added to 290.5 g. of water to give a solution with a vapor pressure of [Y 0.915] mm Hg less than that of pure water at [T1 49] deg. C. The vapor pressure of water at [T1 49] deg. C. is [P1 95.2] mm Hg. (This is a non-volatile solute.)

Here the variables which are randomly generated are N,X, ANS (the answer) and T1; and Y and P1 are calculated as follows:

```
N = 1 + MOD (RD, 20)
X = 500* (.001 + MOD (RD, 1000/1000)
ANS = 0.1 + MOD (RD, 1000)/100
T1 = 20 + MOD (RD, 80)
P1 = 760* EXP (HVAP* (1/373 - 1/(T1 + 273)))
Y +  P1* (1 - X/18/(X/18 + ANS/W(N)))
```

RD is a 7-digit random integer, obtained by calling the random number generator each time it is used. The standard MOD function is used to generate numerical variables within a range of values. The molecular weights W of the twenty possible solutes soluble in water correspond to the chemical formulas stored as the string C$. Note that in this algorithm the answer ANS is randomly generated, and one of the pieces of required data is calculated from it. This technique is sometimes necessary to insure that randomly generated values for all variables are physically realistic. Note also that the vapor pressure of water, P1, is not stored, but is calculated using the Clausius-Clapeyron equation from the heat of vaporization HVAP (stored as a constant) and the randomly generated temperature.

Some of the problem types require algorithms to construct parts of the question. For example, in the electrochemistry and oxidation-reduction problems, there are no oxidation-reduction reactions stored as such. Instead the formulas for the oxidized and reduced forms of a substance are stored in arrays, likewise the number of electrons, the half-cell reduction potential and formula weights. Thus, when a problem requiring the display of half-reactions is created, an algorithm which writes the half reaction in the form of a reduction is called. The algorithm also constructs the net reaction by the following method: From a comparison of the standard reduction potentials, the reduced and oxidized forms which appear on each side of the equation is determined. The stoichiometric coefficients are calculated from the number of electrons in each half-reaction. The equation is then constructed with appropriate number of H^+'s and H_2O's where required. In this algorithm the total number of electrons involved and the net emf are also calculated. An example of a question constructed in this way is shown in Figure 1

USE ELECTRODE POTENTIALS TO CALCULATE THE EQUILIBRIUM CONSTANT FOR THE REACTION AT 25 DEG. C. :

$$6\ Fe^{++} + Cr_2O_7^{--} + 14\ H^+ = 2\ Cr^{+3} + 7H_2O + 6\ Fe^{+3}$$

CALL RXN

GIVEN THE HALF (REDUCTION) REACTIONS: VOLTS/ELECTRON

$$Cr_2O_7^{--} + 14H^+ + 6e^- === 2Cr^{+3} + 7 \cdot H_2O \qquad E = 1.330$$

$$Fe^{+3} + e^- === Fe^{++} \qquad E = 0.771$$

CALL HALF

G = -NE * 23.06 * EOUT

A = EXP (-G/R/298)

Figure 1
An example of a redox problem in which the half-reactions and the net equation are constructed during execution time.

In this example, calculation of the answer required the total number of electrons (NE) and the net emf (EOUT). Creation of this question required the construction of the half reactions as well as the construction of the net equation. Note that this algorithm allows any one of 380 different redox reactions to be created at execution time from 20 stored oxidized form-reduced form data. This algorithm provides the information which otherwise would have required storing 380 reactions, 20 half reactions, 380 emfs, and 380 symbols for electrochemical cells.

In problems which have to do with percentage composition, the percent by weight of each element in the empirical formula is calculated rather than stored. An empirical formula is randomly picked from an array. This formula string is searched for the occurrence of the symbols for the elements. When a symbol is found to be in the formula, the algorithm looks for a number after it. This number and the atomic weight for the symbol are used to calculate its contribution to the weight. The symbol and the number after it are then deleted from the string. This string is again searched for elemental symbols, and so on until the string is null. The percent by weight of each element is then calculated. The same procedure also creates the molecular formula and calculates the molecular weight from a stored factor appropriate to the chosen empirical formula. In this way, all the pieces of information: % by weight of each element, identities of elements, molecular formula and molecular weight need not be stored.

Similarly, chemical equations in stoichiometry problems are not stored as such but are set up from reagent symbols and coefficients. In chemical equilibrium problems, the initial concentrations are randomly generated and it is not always possible to use the approximation that the extent of reaction is small. An algorithm finds new starting concentrations (entirely product species if K is very large or entirely reactant species if K is very small) such as to get a good first guess for the extent of reaction. This first guess and the stored equilibrium constant are used to determine the direction to improve the guess. An iterative procedure is then used to approach the final value. The equilibrium concentrations are then calculated from this. The question may need to display these equilibrium concentrations and ask for the equilibrium constant or the degree of dissociation. An example of this is the following:

WHEN THE SYSTEM

$$I_2 + Cl_2 = 2\ ICl$$

IS AT EQUILIBRIUM, THE CONCENTRATIONS ARE:

(I_2) = 9.02 E-04 M

(Cl_2) = 9.02 E-04 M

(ICl) = 4.03 E-01 M

WHAT IS THE DEGREE OF DISSOCIATION OF ICl?

The $I_2 + Cl_2$ system is only one of many possible chemical systems which are randomly selected.

The construction of a customized set of problems is very painless. An instructor simply accesses the computer on any terminal on campus. Figure 2 shows a typical exchange between the user and the computer. If the user needs no introduction to the system, the documentary is suppressed and he can immediately proceed to type in the number of tests or problem sets he wants. The desired 80-character heading for the test may then be typed in. The user indicates the choice of areas to be tested by typing in a request consisting of three numbers separated by commas. The first number declares how many problems, the second and third bracket the subject area from which the algorithm is to be drawn. For example, typing 3, 5, 18 indicates that 3 problems are to be created using any three of the fourteen algorithms numbered 5,6,7,....17,18. Up to twenty-five such requests are allowed. For each generated test, the numbers 5 through 18 are placed in an array. One of them is randomly selected and removed. The next one is randomly picked from the remaining ones. This is done three times since three problem types were requested. The numbers which have been picked are placed into an array NQ. All the requests typed in by the user are treated in this manner. All the selected numbers go into NQ. When the "end" is encountered, the elements of the NQ array are then shuffled and a call is made to each of the algorithms corresponding to the numbers listed in NQ. Since this procedure is carried out for each generated test, then the problem types appearing in different tests are different.

```
ex test
DO YOU WANT THE DOCUMENTARY?
?no
HOW MANY TESTS DO YOU WISH TO GENERATE?
?50
TYPE IN THE HEADING YOU WISH TO HAVE ON EACH TEST
?Chemistry 112  Final Exam  Summer 1974  Dr. W. Freeman
PLEASE ENTER THE NUMBER OF QUESTIONS OF TYPE RANGE DESIRED.
?3,1,8
?2,27,33
?2,41,46
?4,47,65
?1,91,97
?1,104,110
?end
DO YOU WISH THE TEST ID NOS. TO BE SEQUENTIAL?yes
BEGINNING WITH WHAT NUMBER?1
 JOB 621 ON READER11 -- TSO56100  LCH4397341382956 C JAMESON
FILE SYS00024 FREED
READY
IEF404I TSO56100 ENDED       OPER
```

Figure 2

A typical exchange between computer and user. The last three digits of the number beginning with TSO is the number of the cubbyhole in the computer center output room in which the printed tests can be picked up.

It is possible to generate tests which have the exact same set of problem types, that is, equivalent tests. A request of 1,20,20 will pick problem type 20 specifically. A request of 5,1,5 will include all of problem types 1 through 5 in every test. If all requests are as specific as these, then the program will generate tests which are requivalent. They will still be different in that the chemical systems and the numerical data will be different and the ordering of problem types will be different, but the tests will contain the same collection of problem types. Since the random number generator is seeded by the clock, each time 50 tests are generated by an interchange such as Figure 3, a different set of 50 tests will issue.

Unique problems such as can be generated by this system may be used for problem sets, quizzes, hour or final examinations or as mastery tests for a self-paced course. The uniqueness of the tests or problem sets is an important feature. Difficulties associated with copying are eliminated if each student has his own unique problem set. Security problems associated with testing several classes or sections meeting at different times are avoided. In self-paced courses which feature repeated testing, this system eliminates the difficulties associated with a limited number of test versions.

The tests will be free of typographical errors, which are so difficult to eliminate entirely in secretary-generated tests. The answers provided by the system also make grading easier. The tests are tailor-made according to subject areas requested by the instructor-user, they may be equivalent tests or test with different problem types, as he wishes. The topics and problem types to be included are totally under his control. The input to the program is very simple and interactive (no cards to punch!), thus, making the use of the system completely painless. The cost is very low when compared to a typist. Typically, the cost of a 10-item test would be about 7 cents. This includes connect time, paper, cpu time, and computer center overhead.

Thus, we have a test-generating system which creates unique problems, uses the correct format for chemical symbols (upper and lower case, superscripts and subscripts), results in printed tests or problem sets which are free of typographical errors and are answer-keyed, allows the instructor the choice of topics <u>and</u> problem types to include and requires a painless, very simple input.

This system was written in PL/I and is stored on disk as a load module. It runs in our IBM 370/158 under TSO (time-sharing option). It uses a special print chain for the high-speed printer, with upper and lower case superscripts and subscripts. One hundred and seventy algorithms are presently available. This system as described has been in use for two years at the Department of Chemistry, University of Illinois at Chicago Circle. The first version of this problem-generating system was reported by the author in June 1971 Rocky Mountain Regional ACS meeting in Fort Collins, Colorado.

This program was written in its entirety by the author. Computing services used in this work were provided by the Computer Center of the University of Illinois at Chicago Circle. Their assistance is gratefully acknowledged.

CAI in the CAAI System — Chemistry

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Presented to a Symposium on Approaches to General Chemistry Instruction at the Forty-Fifth, Two Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, May 29, 1975.

The OISE, in cooperation with a number of Colleges of Applied Arts and Technology in Ontario, is currently engaged in a development project in Computer-Assisted Instruction. A Prerequisite Mathematics Skills Program was completed and released for production in September, 1973, and developmental work is proceeding in areas including Technology Mathematics, Mathematics of Finance, Accounting, Chemistry and Electricity. The Participating CAAT's have been responsible for determining and developing the curriculum content of the programs, and the OISE is specifically responsible for the computer-related aspects of these developments.

In Chemistry, the area where students are probably the weakest is that of problem solving and the associated calculations. When the learning algorithm has been determined the computer can be effectively used to give tests, drills, examples, instruction and simulation for either remediation and upgrading or mainline instruction. During the last year such modules have been prepared by a committee of CAAT instructors, Dick Kroeger, Algonquin; Owen Moorhouse, Seneca (Finch); Sandy Sandomierski, Seneca (Lawrence); Bob Woods, St. Clair; Tony Knowles, Loyalist (Project Research Officer).

By September of 1975 it is projected that the courses in Table I will all be available for use on a developmental basis.

<u>CAI Chemistry Objectives</u>

Course I - Basic Concepts
Course II - Atomic Structure
Course III- Modern Theory of Atomic Structure
Course IV - Periodic Table and Bonding (Orbital Approach)
Course V - Periodic Table and Bonding (Non-Orbital Approach)
Course VI - The Mole Concept
Course VII - Basic Calculations and Chemical Equations
Course VIII - Gas Law Calculations
Course IX - The Gas Phase
Course X - Chemical Reactions Involving Gases

TABLE I

Table II is a list of topics which will be added to the course in the future.

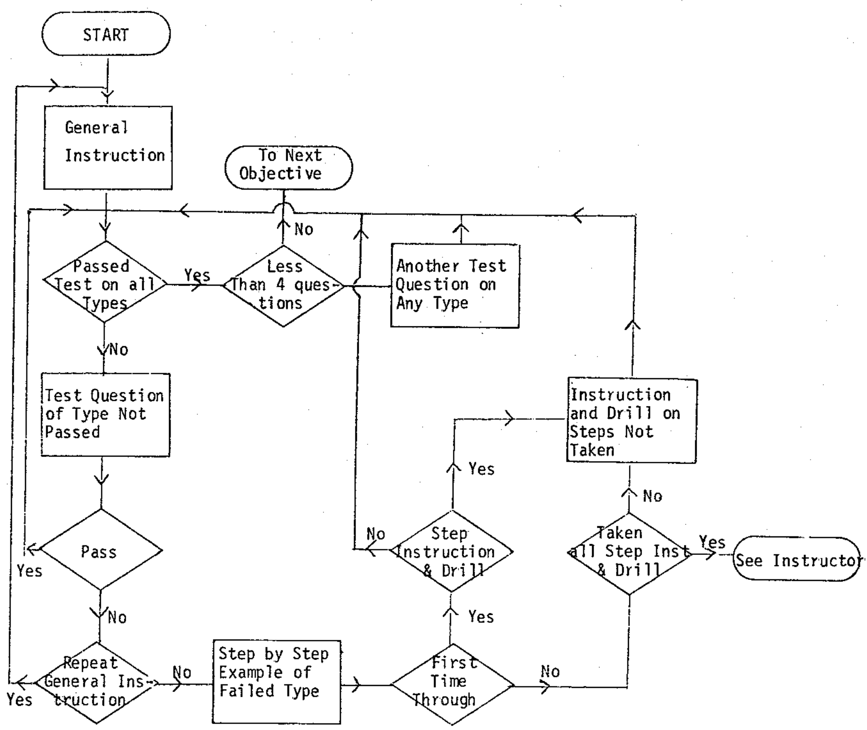
PROPOSED ADDITIONAL CAI CHEMISTRY COURSES

Thermochemistry	Strong and Weak Electrolytes
Electrochemistry	pH
Solutions	Buffer Solutions
Gaseous Equilibria	Solubility Products

TABLE II

The calculation objectives follow the flowchart of Figure I. Wherever possible two or more related skills are combined into one objective. An example of this is the conversion from grams to moles and the complementary skill of converting from moles to grams. The General Instruction preceding a test is designed to speed things up for the student who only needs a memory jog in order to show skill proficiency. When a student requires more detailed instruction a step by step example is first presented followed by a student option to obtain instruction and drill on each step skill. Upon successfully passing each step drill the student must pass the overall objective test to show mastery of the entire group of combined skills. Failure of the objective test again results in the student receiving all instruction and drill not previously taken. A student who exhausts all the instruction and drill is sent to the instructor for further help.

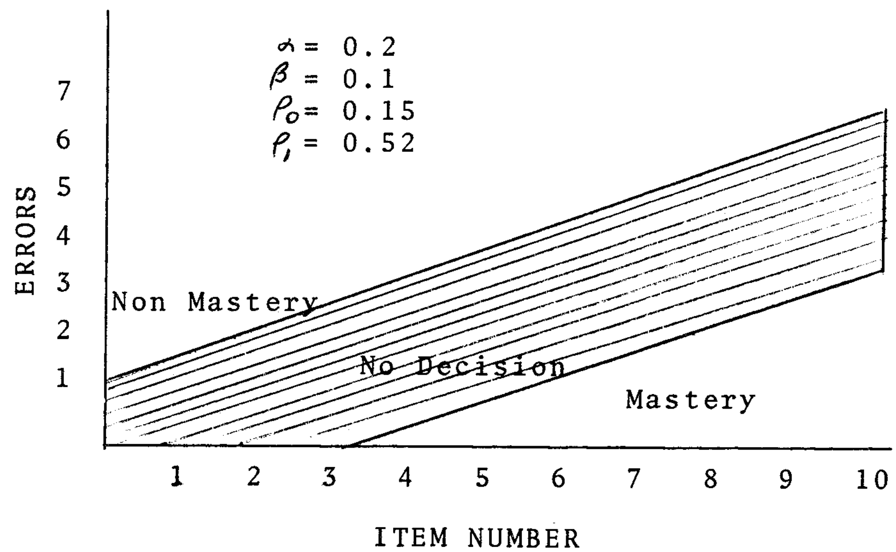
BASIC CHEMISTRY FLOWCHART



The tests and drills in the Chemistry program use the Wald's[1-3] Sequential Probability Ratio Test to determine mastery of an objective. The primary difference between this technique and most non-computer generated testing techniques is that the length of a test is not fixed, but depends on the performance of the student. Using Wald's Test, a student who is entering consistently wrong or consistently correct answers is failed or passed after receiving fewer test items than the student whose performance is more ambiguous. In addition to minimizing testing time, this reduction of the number of test items helps to prevent the boredom or frustration that results when a student who clearly knows or does not know a skill is forced to take a test of a fixed length. The operation of this test can be seen in the gollowing graph where the number of incorrect answers is plotted as a function of the total number of questions asked on the objective. Note that the length of the test is not fixed, but can vary from two to ten questions depending upon the responses of the student.

SEQUENTIAL PROBABILITY RATIO TEST

DIAGNOSTIC TEST
DECISION MODEL



The standard Wald's test parameters can result in a pass for the student when his performance is: four questions taken with no errors, seven questions answered with one error or ten questions with only two errors. A fail results if two questions result in two errors or three questions result in two errors. Once a student makes three errors, he cannot pass in the maximum number of questions (ten), so he fails. There are four parameters, selected by the teachers which determine these pass-fail decisions. A decision of mastery is made and the test truncated if the error rate is estimated to be less than 15%. A decision of non-mastery is made if the error rate is estimated to be greater than 52%. If neither of these conditions is satisfied, no decision is made and the test is continued. In addition to these pass-fail criteria, the α and β

errors have been selected to be 20% and 10% respectively. That is, the percentage of students who are mistakenly placed in the non-mastery area is restricted to 20% and the percentage of students who are mistakenly placed in the mastery area is restricted to 10%.

Another computer dependent technique utilized is the random generation of test items. The computer does not have all possible problems and answers stored in memory. Instead of storing a large set of specific test items related to a required skill, only one model problem is stored. This model problem is parameterized so that it can produce a random sample of test items, drills or examples within the determined limits. Each model problem also has the procedures for the most common mistakes made by students. There is one model problem for each skill, and by using the generative technique for creating specific items the computer storage requirements have been reduced greatly over previous techniques. Of course, computer generation of items also relieves the instructor of this chore while expediting the task of coding and debugging items. Also, the students do not receive the same problems, thus preventing cheating.

In contrast to the tests which only indicate correct or incorrect responses after completion of the entire test the drill questions are immediately followed by a diagnostic message. Wherever possible, common student errors have been anticipated and a corrective diagnostic message is given. In many cases the student must enter the corrected response in order to continue.

The program is designed to meet the needs of students with a wide range of abilities and topic requirements. Three methods of registration are:

(a) Complete Hierarchy
The student takes all the courses with the exception that he takes either course IV (orbital approach to the periodic table and bonding) or course V (a non-orbital) approach to the same material).

(b) Selected Hierarchy
The instructor selects any courses in any order to make up a specific program.

(c) Learner Control
The students are not controlled by the hierarchy structure but may have access to any portion of the program using the available control words.

Two student progress reports are sent out to instructors once a week in order to provide accurate records of each student's activities. When properly reviewed and interpreted, these reports allow a teacher to determine which students need the instructor's personal attention, and in which topics or areas.

<u>CLASS STATUS REPORT</u>

This report lists every student by ID and name who has accessed the program during the specified time period. The last objective accessed by the student and the date of that access are reported. In addition, the total number of tests taken, the total number of tests passed, and the total time spent by the student at the terminal during the specified time period are listed. This report may be used by the instructor to check attendance for the week and detect those students who are progressing through the program at a much faster or much slower rate than the majority of their classmates. Such information could then be used to alter student scheduling so that a student who works more slowly could catch up to his classmates by attending more or longer sessions.

INDIVIDUAL STUDENT PROFILE

This report lists in detail the work that each student has done during the specified time period. Each line of the report describes a student activity. The first column indicates the objective in which the activity took place; the second column indicates the nature of the activity; the third column indicates the level that the objective occupies in the hierarchy; the fourth column contains an entry whenever a test on drill has been taken, and lists the number of test items in the test followed by a slash(/) and then the number of test items which were marked wrong; the fifth column records the time that the student spent on the activity; and the sixth and seventh columns show the date and time of day when the activity was completed. The date appears only when the activity occurs on a date subsequent to the previous activity listed, and the time of day is given in military time.

This report is intended to provide the instructor with sufficient detail to enable him to determine which of his students is experiencing particular difficulties and where these difficulties are. For instance, a student who is failing a large number of step drills and has been referred to the instructor for help, but has not seen the instructor, could be detected by inspection of this report and then could be scheduled to confer with the instructor, or receive additional aid in some other form.

In addition, to the student progress reports which are generated once a week and sent to instructors, a series of four reports are generated semi-annually for the purpose of reviewing and evaluating the effectiveness of the courseware.

The system records data for every test item that a student receives. Included in this data is the student ID, the specific question given, its location in the program, the response entered by the student, and the elapsed time between the presentation of the question and the entering of the student response. Once this data has been collected, it is sorted and manipulated by a series of COBOL programs which reduce the data to a more meaningful form and produce a series of internal reports.

Further statistical evaluation on the effectiveness of the entire program is obtained from the results of tests which are administered to the students before and after course completion. The students also fill out an attitude questionnaire which provides data on their reaction to the use of CAI.

The CAI programms are presently being offered from two computing centers, Seneca College in Toronto and Algonquin College in Ottawa. These materials are available to any educational institution provided that the users participate in the evaluation of programs still under development. The users form the committee which decides the development direction to be taken by the Research Officer. All prospective materials must be reviewed and passed by this committee.

Further information on the Chemistry CAI program should be directed to Dr. Tony Knowles, Coordinator, Tech. Centre and CAI, Loyalist College, P.O. Box 4200, Belleville, Ontario.

STUDENTS ARTICULATING

Industrial Liaison Through Advisory Committees and Work Experience

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Presented as a part of a Panel Discussion on Articulation: High School-College-Industry at the Forty-Fifth, Two Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, May 28, 1975.

Mohawk College in Hamilton, Ontario, has been historically a technological college, emerging from its predecessor the Hamilton Institute of Technology in 1966. While no longer exclusively a technological school, the traditions of Industrial liaison established many years ago are still very much a part of the college situation today. The Division of Technology sets as its primary goal the training of students for technical positions in industry and has always encouraged industrial contacts to aid both in job placement and in helping to establish relevant curricula. Fortunately Hamilton is an industrial city with a wide range of both primary and secondary industry and although it is not heavily chemical in nature there are enough quality control and basic research labs in the city o- surroundings to provide a good selection of professional chemists from which personnel can be selected for liaison purposes with the college.

At the present time Mohawk has eleven technology programs (three year post secondary) and ten technician programs (two year post secondary) including chemical engineering technology and chemical technician programs. These programs are administered by ten separate departments within the Division of Technology and each department has at least one advisory committee.

The technology and technician programs have been created to satisfy both student interest and the community's need for the graduates of these programs. The establishment of any program initially requires the approval of the Council of Regents of the Province of Ontario, and approval is only given if an advisory committee to the college can clearly define a job market. Advisory committees are normally selected by the college from a cross section of community people who have a specific interest in the area under discussion. In the cbemistry area the advisory committee consists of two University professors (one chemistry, one chemical engineering), the science supervisor from the local Board of Education, and nine representatives from industry and government labs, all of whom are functioning chemists or supervisor/managers of laboratories. One of the industrial representatives is an alumnus of the chemical technology program.

The maximum size of an advisory committee is usually twelve people, not counting college personnel who sit as ex-officio members of the committee. The chairman is elected from the committee membership and usually serves a two or three year term. Other committee members are appointed for a three year renewable term although time limits are not rigidly followed and members are added or resign from the committee according to personal commitments. The alumni representative, however is asked to serve a shorter term (no more than two years) in order that a fairly recent graduate can be part of the committee so that program changes can be assessed every two or three years.

The program chairman sits as an ex-officio member for every meeting of the advisory committee and usually takes the responsibility for handling the technical side of the meeting including producing minutes, arranging meetings and setting the agenda. The college also appoints one other administrative person whose responsibilities include general liaison work with all of the advisory committees in the college.

Advisory committees once established become a permanent part of the college scene and may meet as often as four or five times a year or as infrequently as once a year. After the initial task of recommending the start of a new program, the committee assumes other long term obligations to the college such as giving advice on proposed changes to existing programs, reviewing course content to ensure material is not outdated, providing information on the relevancy of certain material to the industrial environment, providing examples and problems for in-course considerations, and assisting in a general capacity with the special projects such as plant visits or work experience.

While the college is not obligated to follow the advice of the advisory committee, the information provided is often accepted willingly and implemented if possible. Pedagogical considerations may take precedence over some idea offered by the committee, however, and in these cases the committee makes no attempt to try and tell the college how to teach or how to organize.

To be effective, the advisors must feel that they are making a real contribution to the college programs. This requires some, but not too much, involvement by each person in sub-committees or in another capacity such as liaison between the college and a particular industry.

At Mohawk College we are just going through an entire curriculum review process for chemical technology wherein the advisory committee established four sub-committees, with members of the faculty on each sub-committee. The role of the sub-committees is to make an in depth review of each course being taught in the chemical technology program. For example, sub-committees were formed for organic chemistry, analytical and instrumentation, physical and chemical engineering, and another for related subjects such as math and physics. Several hours of discussion in each sub-committee will eventually lead to revised course outlines for the entire program. When this job is finished the committee will repeat the process for the technician program.

Positive and continuing feedback such as this makes the advisory committee a valuable asset for the college and helps develop a sense of purpose and involvement with the world of applied chemistry for both students and faculty.

When our technology and technician programs first started, it was apparent that many students were not finding related summer employment between terms at the college and were reaching their final year without any first hand knowledge of what an industrial laboratory was really like. Furthermore, many students were obviously not convinced that many of the ideas and techniques they were being taught were actually used in industry. To attempt to at least partially remedy these problems, a "work experience week" was incorporated into the final year of the program. The format was simple - students spent one week in an industrial lab as though they were a regular employee, but without pay. It was a week of school displaced into another environment. Initially the work period was one week, then we tried two weeks, and have now returned to a one week period. After five years of experience with the program a few conclusions can be drawn and suggestions made for anyone wishing to try a similar approach:

> Generally the work period is considered a success with more students counting it a valuable experience than those who consider it a waste of time.
>
> One week is about the right time in our college giving a reasonable time in the lab, but not disrupting the regular school program too drastically. We prefer the last week in September or the first in October before students are deeply involved with projects, etc.
>
> The experience should be a compulsory part of some other course giving it some credit and making it "count" for something. Our technology students take it as part of their Manufacturing Management course and are required to investigate the companies corporate structure as part of their work report. The technician students take the

work week as part of a Process Industries course.

Students should be given some choice as to the industry they wish to visit. Job interest and geographical location are both important in this respect.

The entire class should be absent from the school at the same time so no one has to catch-up on lost work, labs, etc. This may be difficult if the class is very large and the available jobs are limited. If the class must be split, more active school time is wasted. We have never needed more than sixteen positions at one time.

The objectives of the program must be spelled out for both students and participating industries. Some industries simply assimilated the students into their regular work day with a minimum of training while others put on special programs giving tours, etc. The latter should be avoided since it is counter productive giving the student a tourist status and causing expense and inconvenience for the company.

While not essential for the operation of a work experience program, the advisory committee has been very helpful in our situation. A few phone calls to members of the committee and a dozen positions were made available at about two weeks' notice. We were equally successful with companies who were not represented on the advisory committee but contacts are usually more difficult to make. Only one company gave problems on the question of liability insisting that the college sign release forms absolving the company of responsibilities in addition to having the student sign such forms. The college refused to sign and the Company was not used as part of the program.

In summary, both the advisory committee arrangement and the work experience program at Mohawk have proven to be valuable methods of maintaining a viable liaison between the college and industries in the community served by the college. They are not our only industry related activities but are the most visible contacts that students are aware of and extremely important in keeping our programs up to date, relevant, and visible to potential employers of the graduates.

Articulation: High School-College-Industry Industrial Point of View

John F.C. Dixon
Canadian Industries Limited

Presented as a part of the Panel Discussion: Articulation: High School-College-Industry at the Forty-Fifth, Two Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, May 28, 1975.

What kind of a 'product' is the industry seeking from your program? Since the chemical industry is far from being a homogeneous sector and consists of a broad spectrum of many different kinds of chemical operations generalization poses some difficulties. However, whether the chemical technician or technologist is employed in heavy chemicals production, pharmaceuticals research, technical sales - service, or analytical process control operations, to mention a few quite different types of employment, there are certain qualifications which I believe are required in order to become a successful technologist. I suggest these are the following. My list is not necessarily complete, but I hope it will serve to initiate useful questions and discussion later.

(1) Personal traits

Teamwork is more common and probably more important to the success of industrial operations than the student experiences in the formal educational process. Thus willingness and ability to work closely and harmoniously with others is essential. All activities are interdependent in varying degree and co-operation of trained personnel with different qualifications and related responsibilities is a matter of course. Next, I would list intellectual honesty and integrity. Chemistry is an exact science and its application demands high orders of precision despite temptations to cut corners on occasion perhaps to avoid repetition of a tedious analytical procedure or synthesis. Willingness to accept new responsibilities which comes from interest in expanding one's knowledge and capabilities is another personal characteristic common to successful people and valued by employers. Ability to plan and organize one's work systematically is also most important. Next, ability to communicate effectively both orally and in written reports. We all hear a great deal of flack about this one these days. Unfortunately many otherwise capable people are sadly deficient in their ability to communicate effectively. No matter what one is doing, in the final analysis it must be communicated to someone else to be useful. A fifth personal trait as important as all the others is safety consciousness, with respect both to one's own personal safety and safety of others who could be injured by one's careless work habits. From an employer's point of view the safety of employees is an important social obligation as well as making sound economic business sense.

The foregoing personal qualifications are sought in all potential employees regardless of the level of education or type of job to be filled. Obviously they are the product of many environmental factors and while formal educational programs alone cannot instill these qualities in people they can make a large contribution, especially in developing intellectual honesty, and abilities to plan, organize and communicate effectively.

(2) Professional Abilities

The following group of characteristics apply more specifically to graduate chemical technologists. These are what might be called professional abilities as opposed to the more general personal traits first mentioned. A technologist must have good manual dexterity and some skill at drawing and sketching. In most cases his or her activity involves implementing some operation whose theoretical aspects have been developed by others with a more intensive education in theory. I have seen many intelligent chemists with post graduate degrees who were rather helpless when they had to set up and operate equipment necessary to check out a process they had conceived. Knowledge of modern analytical equipment is essential. As you well know there has been a great proliferation of ingenious devices which today greatly simplify the procedures and reduce the time required to get analytical information. This knowledge should include an understanding of the principles involved and how to make minor repairs. Instrument specialists are not always readily available and often the required repair is of a relatively minor nature, but crucial to continuity of operation. I understand that your programs are aware of and stress these requirements.

Ability to follow an analytical or experimental procedure precisely is perhaps stating a rather obvious requirement. However, some procedures are quite complicated, such as a multi-stage sequence of syntheses in a pharmaceutical preparation where one starts with many kilograms of initial raw material and under the best of circumstance may produce but a few grams or even milligrams of final product only through careful manipulation.

Next I list ability to recognize significant phenomena during such chemical analyses or synthesis when a reaction is not performing as intended. In some cases such observations can lead to important improvements. I suggest that such observational ability is in part dependent on a reasonable foundation knowledge of chemical and physical processes. Though of course not as intensive as expected in university honours chemistry programs.

A good mechanical knowledge of common chemical process equipment as employed in pilot laboratories and multipurpose chemicals specialties manufacture is most useful. I refer to pumps, motors, mixing devices, separation devices such as centrifuges, filters, screens stills etc., finishing compounding and packaging equipment. This could ideally include also some contact with high pressure equipment, how to handle compressed gases and gases liquified with cryogenic equipment.

These then are the important industry requirements as I see them. Perhaps from a teacher's point of view they are expressed in a rather too general fashion to be translated readily into an appropriate program of courses. When industry people are asked for opinions about curriculum they have difficulty interpreting the program outlines because the course descriptions do not convey a clear picture to the layman of the depth and scope, especially of the theoretical coverage. Outlines I have seen tend to suggest that the program is similar to an advanced university chemistry program, but understanding can be improved by reading samples of examination papers. In my view the best way to get constructive assistance from industry people on curriculum content is by involvement in joint advisory boards composed of teachers, student representatives and interested employers having a chemical background.

Students who have the opportunity for direct part-time work experience before they graduate are potential sources of useful input on industry requirements. Unfortunately summer employment continues to be rather haphazard for the majority of students, both college and university, because there are apparently never enough suitable jobs for everyone. The sandwich and cooperative arrangements are generally agreed by educators and employers to be near ideal but the system can only accommodate a small fraction. Perhaps part of the fault lies with industry in not making sufficient effort to participate in such programs or realize the longer term benefits in simplification of recruitment and reduction of turnover as results of better matching of people and jobs. I believe that more efforts to increase industry involvement in advisory councils would be rewarding. I am convinced that the chemical industry for one does not generally appreciate the quality of education provided in technology programs today and continues to recruit chemists and chemical engineers for certain jobs which would be better suited to chemical and engineering technologists. This is in fact a message which the Human Resources Committee of the Canadian Chemical Producer's Association is currently attempting to convey to CCPA member companies.

Most companies will respond to requests for collaboration on educational matters if properly approached. Many colleges have established useful arrangements with local industries and businesses. Ideal working contacts should be professionals somewhere in the middle management area. Such people are closer to the action, closer in age to the students and more familiar with appropriate young staff members who can be drawn into meetings from time to time. If a suitable person or persons in a particular company are not known to the college the company should be approached initially at a senior lavel - the president, or vice president concerned with personnel. Usually they will respond to an appeal which suggests some of the potential benefits to the company, such as future staffing which can result from collaboration. Also, corporations are putting increasing emphasis on activities which relate to a growing sense of public affairs responsibilities.

SPECIAL TECHIQUES IN CHEMICAL EDUCATION

An Interdisciplinary Approach to Science

Jeff Kelly
Mike Veug
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Presented to a General Session of the Forty-Sixth Two Year College Chemistry Conference, Clark Community College, Vancouver, Washington, September 20, 1975.

I. Description of the Evergreen State College

A. Physical Description

1. State supported 4-year college - undergraduate only
2. Located on Cooper Point near Olympia, Washington - the state capitol
3. The campus size is nearly 1,000 acres with roughly 1/4 mile of salt water front
4. The enrollment limit is now 2,587 students. The enrollment is currently under legislative mandate to increase by about 200 students per year.
5. Student faculty ratio currently is 21 to 1.

B. Philosophy

1. Evergreen was designed to provide an alternative to traditional education.
2. Interdisciplinary studies are emphasized.
3. The location at the seat of state government is to facilitate governmental liaison and interactions with state agencies.
4. Students do not enroll for a series of classes, but are engaged full time in one of three modes of study: coordinated studies, group contracts, and individual contracts.
5. External credit may be granted for learning outside of the college. Students are encouraged to participate in one or two quarters of internship for on-the-job experience.
6. Faculty work full time in a program or full time with their contract students.
7. There are no graduation requirements - a student's course of study is developed by the student with the assistance of the faculty sponsor. The B.A. is the only degree.

8. There is no faculty tenure, faculty are evaluated annually and are appointed on three-year contracts. There is no faculty rank other than "Member of the Faculty".

9. There are no departments, but faculty meet together in shifting natural groupings.

10. Evaluation is the cornerstone of operation at Evergreen.

    a. Rather than a grade, each student receives a one-page narrative evaluation from the faculty sponsor for each quarter of work. The student also writes a self-evaluation.

    b. A student transcript is composed of a program description or contract copy, the faculty evaluation, and the student evaluation for each quarter of work.

    c. Students write a written evaluation of faculty that becomes a part of the faculty portfolio.

    d. Faculty write evaluations of each other.

    e. All administrators are evaluated annually with input from all constituencies.

II. Description of the learning modes

A. Coordinated Studies

1. General characteristics

    a. They usually involve 60-100 students and three or five faculty members, all engaged full time in the chosen course of study.

    b. They are designed and changed every year, always focusing on central problems or themes in an interdisciplinary fashion.

    c. The programs may be designed by a small group of faculty, a group of students, or faculty and students working together.

    d. The program may be one or more quarters long and may start any quarter.

2. Level of Study

    a. Basic programs are always designed to be broadly interdisciplinary.

    b. Intermediate and advanced programs may be divisional (e.g. deal mainly with science) or may be broadly interdisciplinary.

3. Sample programs

    a. Basic (eight programs available in 1975-76).

i. "Science and Culture: Beyond Specialization" is designed to examine the nature of disciplinary specialization, its origins, and where it's leading us via a historical study of the origin and development of natural science and a look at cultural implications (three quarters).

ii. "Health: Individual and Community": from a biological, psychological, and social point of view for students starting towards fields such as health, psychology, social work, environmental science, medicine (three quarters).

iii. "Ethics and Politics" will progress from a study of individual ethics, through social ethics to political action (three quarters).

B. Group Contracts

1. General Characteristics

a. Formally arranged learning contracts for 15-25 students, usually centered around a specific theme.

b. An advanced mode of study based on a proposal generated by a faculty member, a group of students, or a faculty-student collaborative team.

c. Students and faculty work full time on one group contract.

d. The general duration is for one quarter, but programs may last over one year.

2. Sample programs (chosen from over thirty group contracts currently offered, nine in the sciences).

a. A Cultural and Social History of Art and Architecture in Greece, Rome, Medieval and Renaissance Europe (three quarters).

b. "The Artist Class" combines intensive studio workshops with substantial reading, discussing and serious thinking (two quarters).

c. Introduction to Microbiology (one quarter)

d. Microbial and Molecular Genetics (two quarters)

e. Biochemistry (two quarters)

f. Marine Organisms and Estuarine Environments (one quarter).

C. Individual Contracts

1. General Characteristics

a. The most diverse study mode on campus available to advanced full and part-time students.

b. The contract is proposed by the student and negotiated with a faculty member.

c. The course of study must be in an interest area of the faculty member, be a worth-while course of study, be better accomplished independently than in another mode of study.

d. The student works independently (sometimes partly with a small group) and meets generally once every week with the faculty sponsor.

e. The student may sub-contract and thus for part of the work consults with another faculty, staff or resource person.

III. Other Special Learning Modes

A. Cooperative Education

1. An academic support program designed to utilize learning resources in the community through paid or volunteer student internships.

2. Provides real world experience and on-the-job training often opening up job opportunities immediately upon graduation.

3. Provides about 800 interships per year, 80 in the sciences.

B. Modules

1. Designed to teach a specific skill area (e.g. general chemistry, algebra, mycology, life drawing, writing) and be equivalent to a four quarter hour course. There are 10-20 offered per quarter.

2. Meetings held late afternoon or evening to encourage community participation and not interfere with scheduled program activities.

3. Open to full time students (one module may be taken per quarter) or part-time students.

4. In the sciences, the modules are often designed to provide basic prerequisites.

C. Learning Resources Center

1. Maintained to provide vasic and remedial skills in reading, writing and mathematics.

2. Staffed mainly by faculty on a rotating basis.

D. Self-Paced Learning Center

1. Features

a. Video-tape, slide-tape, and computer interactive self-paced learning modes in all fields with a strong focus on natural sciences.

b. Contains gas chromatographs, balances, colorimeters, spectroscope, air tracks and other basic science equipment set up with self-paced learning experiments for skill acquisition.

2. Purposes
   a. Designed to self-teach basic course material (e.g. logarithms, chemical nomenclature, gas laws) and self-teach techniques (e.g. recrystalization, gas chromatography, computer programming).
   b. Enables a student engaged in a research project to review a specific needed subject area or to learn how to operate a necessary piece of equipment.

IV. Curricular Pathways in Science (Table I)

TABLE I
Curricular Pathways in Science at TESC

First Year - Basic Coordinated Studies

Nat. Sci./Humanities	Nat./Soc. Science	Nat. Science/Art	Technologies
Science & Culture	Political Ecology Nature & Society Life & Health	Harmony in the Universe Space, Time & Form	The Good Earth Marine History & Crafts

\+ Possible Language or Math module (algebra, trigonometry)

Second Year - Divisional Coordinated Study or Group Contract

Foundations of Natural Science		or	Biology Contracts	or	Modules
physics chemistry calculus some biology computer programming	Developmental Biology Linear Algebra & Dif. Eq. Organic Chem. Computer Modeling		Marine Biology Evergreen Environment Forestry **Ornithology** Field Biology Land Use Planning		general chem intro.organic chem gen. physics genetics (calculus) statistics

Third & Fourth Years

Advanced Coordinated Studies		or	Group Contracts	or	Individual Contracts	
Technospheres Environmental Design	ECOP Evergreen Environ. Marine Biology		Biochem/Mol. Bio. Microbiology Physiology/Anatomy Neurophysiology		Advanced Physics-research proj. Astrophysics-internships Kinetics-skills develop- Computer Design Ad. Org. Analy. Chem Optics	ment or background completion

Comparison of the Traditional Method and the Programmed Method of Instruction for a Unit in General College Chemistry

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Presented to a Symposium on Allied Health Chemistry of the Forty-Seventh Two Year College Chemistry Conference, Shelby State Community College, Memphis, Tennessee, November 1, 1975.

INTRODUCTION

In this paper the results of a comparison of the lecture method (traditional instruction) with the programmed method of instruction for two units in General College Chemistry are presented. This study attempts to determine two things:

1. By which of the two methods of instruction will a General College Chemistry student achieve the most when given equivalent time.
2. By which of the two methods of instruction will the student prefer to be taught based on these units of study.

BACKGROUND AND SIGNIFICANCE

This study was undertaken for several reasons, one of the most important being that we have been involved extensively in developing programmed instruction in chemistry at Central Piedmont Community College during the last three years. This development was done without our having made any studies dealing with the comparison of student achievement using traditional instruction with student achievement using programmed instruction. Thus, an obvious need existed for this type of evaluation in the field of science and especially, chemistry.

Much local interest in comparing the traditional lecture method with the programmed method of teaching General College Chemistry came about as a result of a six weeks graduate course in curriculum planning attended by the chemistry facult;y of several community colleges in this immediate area. This course was offered in 1972 by the University of North Carolina at Charlotte Chemistry Department with the help of several visiting consultants. This question of traditional versus programmed instruction was discussed at length with very little data available for evaluation.

The need for improved instruction in the field of chemistry is shown by the very low percentage of student success in practically all levels of chemical education from high school on through the typical four-year college and higher. (Of the students who start toward a Ph.D. in chemistry, less than three percent attain the degree.) This problem is especially apparent in the teaching of chemistry in the typical community colleges and technical institutions where the open door policy yields an extremely heterogeneous group with respect to ability and background in chemistry.

Chemistry has long been (and still is) a basic subject needed for many professions, and it has been the course used to "week out" the weaker students in such fields as medicine. Having had considerable teaching experience in math, biology, and chemistry, I can say without any reservations that chemistry is the most difficult of the three for both the student and the teacher. We need improved instruction in the field of chemistry more than any other field of Science.

A response to this need for change in instructional methods in all fields is indicated by a change in the basic philosophy of teaching. A good example of this is the philosophy of Central Piedmont Community College as presented in the college catalog:

> "The doors of Central Piedmont Community College are open and accessible to all adults seeking to further their education. The College recognizes its responsibilities to the community by providing general services to the surrounding area; by helping each student recognize his potential as a worthwhile and productive member of society; by providing opportunities for each student to develop his physical, intellectual, and esthetic capacities according to his desire to pursue an education; and by assisting each student to attain goals consistent with his needs, interests, and abilities,"[1]

The changing philosophy of education and the problems encountered when it is applied in the two-year college or technical institution is well illustrated by Herrscher:

> "The national commitment to equality of higher educational opportunity and to accountability for student learning has created many complex problems, at the center of which is the need for significant modifications in traditional methods of college-level instruction. Sweeping changes in instructional methodology are necessary to accommodate not only the educational aspirations, but the fundamental and pervasive learning problems of large and growing segments of college populations which are obviously not composed of traditional college-level students. Otherwise, "equal opportunity" may prove to be merely another illusion to the very students (i.e., low-achieving, minority groups, socio-economically deprived, culturally disadvantaged, handicapped) for whom it should have the greatest meaning. To date, equal opportunity in higher education has been more a slogan than a fact, for as many as 75% of low-achieving students withdraw in the first year.[2]

In his book, Catching Up: Remedial Education, Roueche says:

> "Because of the widely proclaimed open-door admissions policy, many of those who entered community colleges were low-achieving, nontraditional students (Moore, 1970, refers to them as "high-risk students") who had little chance of achieving academic success in traditional colleges."[3]

The changing philosophy and new approaches to education instruction require constant evaluation of instruction for improvement and direction.

In a comparison of TI and PI in 15 field experiments, Silberman found (1962) that all of them showed that PI took less time to complete than TI, and in 9 of the studies, students in the PI groups scored higher than those in the TI groups.[4]

A survey by Schramm (1964) of 36 studies comparing PI and TI revealed that of these 36, 18 showed no significant differences in performance between PI and TI groups, 17 showed a significant superiority for PI and only one showed superiority for TI.[5]

In a more recent review, Lang (1972) reported that between 1960 and 1964, 112 comparative studies were conducted that aimed at matching PI and TI. Of these studies, 41% showed PI to be superior, 49% found no difference, and 10% found PI to be less effective than TI.[6]

It appears, on the basis of the research to date, that it is reasonable to conclude that PI is generally as effective as TI and may result in decreasing the amount of time required for a student to achieve a specific educational goal.[7]

In his "Individual Approaches to Chemistry Versus Group Lecture Discussion," Hunter found a higher level of achievement when the individualized programmed approach was used than when the lecture approach was used. This held true both on the unit test and on the final exam, especially the latter.[8] This study, however, is one of the few studies that has been made in the field of chemistry. No comparative studies in chemistry in which all the variables held constant, including the amount of time spent on the topic, were found.

Many people have asked the same two questions this study seeks to answer:

1. By which method do the students achieve the most learning in chemistry when conditions and time (class and homework) are equal?
2. Which method do the students prefer for chemistry?

PROCEDURE AND RATIONALE FOR ACTIVITIES

The activities and rationale for each activity are listed and described in this section.

1. Using the systems approach, two very similar General Chemistry programs were written, student tested, and revised. The two packages were also critiqued by other chemistry instructors and evaluated as excellent by Dr. John Roueche of the University of Texas. Included in these packages were pre and post tests. A slightly modified systems approach was used in development of the programs. This approach, called "CISTRAIN,"[9] requires that the self-evaluation items (tests) be written first and then the descriptive objectives. The order in which the components of each package were developed is as follows:

a. self-evaluation (test)
b. descriptive objectives
c. discussion of self-evaluation (answers to test)
d. practice exercise items (learning exercises)
e. discussion of practice exercises (answers to practice exercises)
f. study review
g. introduction

This slightly modified systems approach was used in the development of these two units because this method of programming is being used in a great number of institutions across the country. It has also been applied in the development of a large portion of our general chemistry courses at Central Piedmont Community College. This approach has been considered to be successful here and elsewhere.

The objectives and pre-test items stated in the program packages were duplicated and given to each participant in the lecture section to insure that in each section, the student would cover the same material. A copy of these are included in the appendix.

2. Audiotapes (cassette) were made for use with the packages. These tapes provided further discussions and answers to questions and problems. Audiotapes are very commonly used with this type of instruction and have been found to be very helpful to many students. They are a regular part of our general chemistry program at Central Piedmont Community College.

3. A pre- and post-test were developed and then critiqued and checked by several advanced chemistry students and by four instructors. This material was a part of the package that Dr. Roueche evaluated. Criterion reference testing was used on the post-test. These tests were given for two reasons: (1) to aid in placing the 30 students into two equal groups, and (2) to measure the amount of learning that took place by both the lecture and programmed packages.

4. The population sample was selected from a general chemistry class at Central Piedmont Community College and placed into two equal groups on the basis of the pre-test score and on the basis of their class grade average up to that point. (The two groups each had 12 numerical grades and almost identical averages.) The class average has been found to be an accurate predictor for the future success of a student in chemistry.

5. The students in both groups were briefed at the same time on the purpose in conducting the study, and they were given the necessary background for the unit to assure that each student had equal footing in terms of what "he should now know".

6. A student evaluation questionnaire was compiled, and it isincluded in the appendix. The questionnaire was completed for two reasons: (1) to determine which of the two methods of instruction students preferred and (2) to assure that both the lecture and programmed instruction was at least of an acceptable quality for a scientific comparison. (This was very important for the lecture.)

7. The unit on molarity was taught to the two groups. One group used the programmed method while the other group used the traditional lecture discussion method with both groups given equal amounts of time. No participant was permitted to remove any tape or written material from the rooms.
   The molarity unit was taught first, to present a logical sequence for the two packages. Both groups were given ample and equal amounts of time to complete the unit because this was to be one of the main points of the studv--to see by which method they learned the most in a given amount of time.

8. The unit on normality was taught to the two groups, one using the PI approach and the other using the TI approach. In the second lesson, the two groups were switched so that both groups used both methods on similar units.

9. Both groups were post-tested together to obtain gain scores. The post-test and pre-test had five questions on each of the two units, and the questions were designed to test the stated objectives in the two units: criterion-referenced, in other words. (See appendix for pre- and post-test.)

10. The students evaluated the lecture and programmed methods via a questionnaire. Again, the evaluation was made to assure that the quality of instruction was high for both methods, especially the lecture, since the programmed method had been thoroughly evaluated before the study. The evaluation was important also to determine which method they preferred. (See appendix for questionnaire.)

11. The results were compiled and are included in the following sections. A brief outline of the procedure followed in this study is included on the following page.

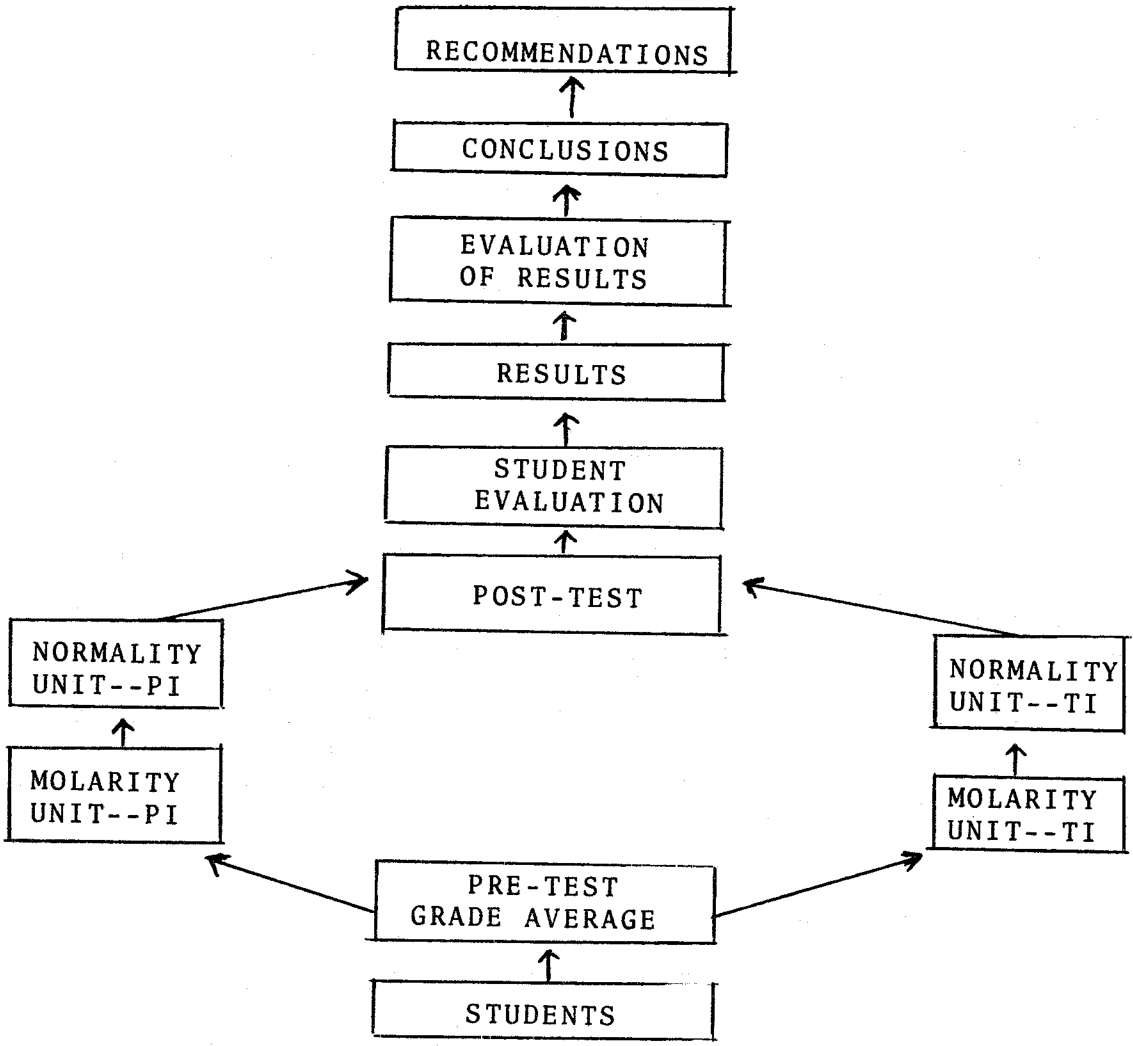

TABLE A

DESCRIPTION OF LEARNING ENVIRONMENT

Lecture

Fifteen students were taught in a typical classroom, using the chalkboard for problems, etc. The students were given a list of objectives along with practice exercises on a handout (copy in appendix). Students showed much enthusiasm for the unit in lecture and frequently became involved in open discussions. The lecture lasted about one hour for each topic.

Programmed

Fifteen students were taught by a written program (copy in appendix) in a room that had study carrels. Each student used the following items: (1) written program, and (2) cassette player with head set and tape. They were left with very little supervision--no help was given concerning the chemistry topic. The time was exactly the same as lecture.

RESULTS

The data obtained from the study was treated as described below:

1. Item analysis was run on the pre and post tests.
2. The mean gain score was compiled and determined for the lecture and programmed methods.
3. Student's t-test was applied to the mean gain scores for all the students for the programmed instruction and lecture instruction.
4. The results of the student questionnaires were compiled and evaluated.

"Item analysis" was run on both the pre-test and post-test to determine if they were good tests. This item analysis included the following points: (1) difficulty index, (2) item variables, (3) point-biserial correlation coefficient, (4) reliability estimate (as computed by the Kuder-Richardson method), and (5) the standard error of measurement. These results are included in the appendix. According to Dr. G.J. Brenner[10] in his "Explanation of Item Statistics," the results on each of the above computations on the pre-test and post-test were good to excellent for some and acceptable for all of the others. This justified the use of these tests for this study.

The average gain score found for the programmed instruction and the lecture instruction on each of the units is shown in the following table:

Average Gain Scores on Each Unit

	Molarity	Normality
Lecture	1.47	2.00
Program	1.87	2.07

NOTE: The number of questions on normality and molarity in both pre-and post-tests were five each.

The average gain score for both the molarity unit and the normality unit was higher for the programmed instruction.

The average gain score for both the units by each method of instruction is shown below:

Average Gain Score for Both Units

Method	Mean Gain Score
PI	1.97
TI	1.73

Again, the average for programmed method was higher than the average for the lecture method.

To determine if this difference in mean gain scores was significant, student's t-distribution test for the difference between means was applied.[11]

In order to apply student's t-test, two basic assumptions are made concerning the population. They are:

1. The population sampled must be normal.
2. The population variance must be homogeneous (the same)

It was found that at the 95% confidence level no significant difference exists between the mean gain score for the programmed method and the lecture method for these two units in chemistry.[12]

As a result of questions asked for students responses the students felt the objectives were clearly stated in both the lecture and in the programmed methods. A slightly larger percentage of the students felt they had accomplished more of the objectives in the lecture than in the programmed method. The results also show that students feel the lecture appears to be a little more interesting, varied, and personal.
Overall percentages are shown in the following table.

Student Method Preference

Lecture Method	35.4 Percent
Programmed Method	25.8 Percent
Some of Both	38.7 Percent

CONCLUSION

Some studies have shown that programmed methods of instruction are superior to traditional methods of instruction. Other studies have shown just the opposite to be true. In this study the following was found:

1. There was no significant difference in achievement when the two different methods of instruction were used for two very similar units in general chemistry where the amount of class and study time was constant. Three very important points should be noted concerning the two methods: (a) The student learned at least as much by the PI method as with the TI method without the presence of an instructor; (b) The development of the material used in the PI required much teaching experience and a large number of instructor hours; and (c) In this case the lecture was evaluated very highly whereas often this is not the case.

2. The students liked certain aspects of both methods of instruction although, overall, there was a slight preference for the traditional method. Most significantly,

the students indicated a strong preference for using some of both methods.

RECOMMENDATIONS

1. Both methods of instruction should be employed in the teaching of general chemistry at Central Piedmont Community College. Programmed units should be used for material that lends itself to that kind of instruction. The traditional methods should be used in other cases.

One method of instruction should not be used exclusively; full advantage should be taken of both methods i.e. use the PI method where it has shown to be equally effective and give the instructor release time to improve both PI and TI methods of instruction.

2. The administration should strongly encourage the faculty to make more studies of this type to determine which methods of instruction are best suited for different subjects before selecting any one method.

3. Since this study revealed, surprisingly, a high degree of student knowledge on different kinds of instruction, student feed-back should constantly be used in all methods of instruction.

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Individualized Evaluation of a General Chemistry Course Using a CMI Approach

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INTRODUCTION

A rather extensive set of computer programs have been recently developed at El Centro College, Dallas. The program system which uses APL-PLUS is capable of test generation, grading, and recording test results of students individually or as a class. In addition, the system may be used to store lab and homework results. The retrieval of this stored material as well as a final grade result of each student may be obtained either on computer typewriter terminal or lineprinter.

It was thought possible to utilize such a grading and recording system in an individualized testing approach using a Science Majors Chemistry, Chemistry 101-102. The idea was inspired by such commercial approaches as the Keller Plan. It was thought that students should be given more responsibility in determining the degree of mastery in chemical concepts. An evaluation of the program is currently underway in order to ascertain the effectiveness of such an approach.

TEST GENERATION

The initial stage of this study involves the selection and computer generation of exams. As many as four different versions of the same exam were generated. The test items are selected by the instructor from test questions (multiple choice and true-falst) previously stored in computer test files. The items are randomly generated, and the keys of each version are stored in a computer grade file created for that course. In addition, the keys are printed out on paper for the instructor's records. For security reasons the keys are coded so that any unauthorized retrieval would result in gibberish for the unauthorized retriever. Each of the test versions are reproduced by spirit masters. A total of ten separate exams of four versions each were generated and stored in the above manner for this program. Any test version is capable of being replaced which will automatically replace the old key in storage with the new key as the test is being typed out on the computer terminal.

TEST ADMINISTRATION

At the beginning of the semester, a list of concepts for each test is identified for the student. The test booklet consisted of an instruction cover sheet, the test items, and support materials such as a Periodic Table of the Elements and log tables. The student could choose from 15-20 hours a week in which a version of the exam could be taken. Each exam attempt was able to be completed within 30 minutes on the average. When the student felt ready to attempt a test, he would come to the test room during the scheduled hours and receive a test booklet, answer sheet, and a piece of scratch paper. After marking the answer sheet, the instructor and student would go to a computer terminal. The instructor would sign the student on with the student's personal code number and load in a computer program that would grade the test using the appropriate stored key. Before grading can begin, the student must identify the course name and the code number for the test when asked to do so by the program. After supplying this information, the student is instructed to enter the choice for each test item on a separate line. After each choice has been entered, the computer program gives the student a chance to change answers to items by identifying test item and new choice desired. After all corrections have been made, the student receives an immediate feedback analysis which includes number of questions in the exam, number answered correctly, question items missed, percent, and a "pass" or "not passed" statement. The test results are automatically stored in the compute- file. In addition, an accumulated test average of all previous test results is printed out, and the program terminates by disconnecting the student from the terminal.

Occasionally, the main computer system malfunctioned. When this occurred, the test could be graded by hand using the printed key in the instructor's possession. The result could then be recorded in the computer grade file by the instructor using a sub routine called "PLACE". Any grade result could be changed by using a "REPLACE" sub routine or might be deleted entirely from the student's record by using a "DELETE" sub routine. Once a student's result has been recorded for a particular test version, it is impossible to regrade that version on his own. Only unless the instructor deletes a result from the record for a particular version, can that version be used again by that student.

After a student has received his graded results from the terminal, he reviews each missed item. The instructor then goes over the missed items that the student does not understand which generally takes 2-5 minutes per student. This period allows the instructor to identify concepts giving difficulty and a chance to suggest supplementary material for review before another possible attempt. Such material includes A-V and CAI packages. The student is given a "guideline" date for each of the ten tests taken which paces the student throughout the semester. If the student receives less than 65 on a test version, another version of the test must be attempted at some near future date. This procedure is continued at the discretion of the instructor. Any student receiving 65 or greater may improve his position, it he desires, by taking other versions. The highest grade of all attempts is recorded in the computer grade file. However, time is a principle factor in this program. In order to prevent students from getting too far behind thus penalizing themselves at the end of the semester, a seven day time limit beginning with the guideline date has been instituted. After this time period, decision as to taking more than one version for an exam rests solely with the instructor. The lateness of the attempt and the test result usually guides the instructor in deciding whether further attempts should be made past this time limit. No student is turned away from the first attempt no matter how late it may be taken. 25% of all tests are replaced annually on a rotational basis. All test materials including scratch paper is returned to the instructor in order to prevent wide dissemination of test materials.

SUPPLEMENTARY SUPPORT MATERIAL

Supplementary audio-visual material includes commercial and custom designed film strips utilizing audio cassette portions. In addition, super 8 mm single concept cartridges were available for certain concepts.

There is at least one chemical review computer package which quizzed students on the concepts to be tested for each exam. The interactive packages responded with hints when a student answered a question incorrectly and gave the student an evaluation of the questions attempted in the package. The packages consisted of multiple choice and single answer math problems in chemistry. The student decides at the beginning of the program how many questions will be attempted at a single sitting.

OTHER RECORDING FUNCTIONS

In addition to storing test results, the instructor may record lab reports and homework results if it is part of the course. As with each test version, each separate lab report and homework is identified with a code number. Each grade may be recorded for a single student using a "PLACE" sub-routine or a grade may be recorded for the entire class using a "MULTIPLACE" sub-routine. Deletions and replacements are also possible.

RETRIEVAL OF GRADES

The grades that have been recorded for tests, lab reports, and/or homework may be retrieved by the instructor for an individual student as well as a whole class. The retrieval of an individual's grades may include all test attempts; however, only the highest test grade for each test is used to receive a test average which is printed beside the student's name and code number along with the highest attempt for each test. For lab reports and homework, the individual grades and total point accumulation is printed out along side the student's name and code number. The program gives the instructor a chance to receive a final grade report. If this is asked for, the instructor must identify the grade contribution for each level of evaluation. During the final grade printout, the total test, lab report, and homework points are recorded beside the student's name and code number. The listing is different from the test, lab report and homework printouts in that the students are listed beginning with the highest point total and proceeding downward.

Usually such a printout as described above takes longer on the computer terminal which prints only one character at a time. The instructor may receive access to the line printer and receive the same printout and as many copies as needed in a fraction of the time. This is particularly useful for final end of semester reporting of grades to the administration.

At any time during the semester, the student may retrieve his own grade results which may be used to evaluate progress in the course. The student need only to load in the program and identify the course name. The program lists the grade results and terminates by disconnecting the student from the computer.

CURRENT STUDENT REACTION TO THE PROGRAM

Only students in the first semester of the course have been asked to evaluate the testing approach, and the results of such an evaluation have been summarized in Table I. Thirty-four students participated in the evaluation. Although the results of this evaluation, in themselves, is not conclusive, they do give an indication as to student attitude for this approach when compared to a more traditional testing approach. For example, a clear majority of the students thought the new approach superior to the traditional one-shot approach to testing (61.76%). Students were particularly appreciative of the immediate feedback and consequent guidance by the instructor. Most students felt that the number of tests (10) and the number of test items on each test (20) were about right. Typical verbal comments included "It's OK to me like it is." "This takes pressure off the student. It's great!" "More computers to grade tests so you won't have to wait so long." "Program is good but a few more hours for taking the test should be added." "Tests are too simple." "Testing program ideal."

In comparing the effect of this approach on student attrition rate in the course, a slight decrease in student attrition was noted, 48% with traditional approach versus 44% with this approach.

Generally, student attitude as perceived by the instructor was enthusiastically positive throughout the semester.

No comparative studies as to achievement level have been made as of this paper. However, it is believed by this author, that ample student response has been demonstrated in order to support the continued development of this approach.

The IBM answer sheets for the separate test versions will be analyzed by computer this spring. The discrimination index as noted by the value of each item will be used to eliminate poor test items. Hopefully in this manner, better test versions can replace the ones being used now.

TABLE I
Student Attitudes on Testing Program

Question	Response
How do you rate the present testing program in Chemistry 101 compared to the traditional scheduled one attempt?	Superior 61.76% Better 23.50% Same 2.94% Inferior 8.82%
Number of Hours for Testing	Too many -- About right 73.53% Too few 26.47%
Total number of tests in the program.	Too many 2.94% About right 97.06% Too few --
Availability of grade result	Excellent 67.60% Good 20.60% Average 8.82% Poor --
Availability of guidance after testing	Excellent 44.11% Good 41.2% Average 11.80% Poor 2.94%
Attitude of instructor giving tests	Excellent 32.40% Good 50.00% Average 20.60% Poor --
Number of test items on each test	Too many -- About right 94.00% Too few 6.00%
Do you feel that you are understanding the concepts better than without such an approach?	Yes 32.40% No 26.4% Possibly 26.47% Cannot tell 14.70%

Number of students 34

Information Processing and Learning Theory

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THE PERCEPTION OF ENERGY

Just what _is_ energy?

Most dictionaries and some physics textbooks suggest that "Energy is the capacity to do work". But during the past century and a half we've learned a very great deal about energy. We've gone far beyond Aristotle's coining of the word two millennia ago, and we've learned, among other things, that something called _free energy_ is more appropriately the capacity to do work. Physicist Richard Feynman answers the question with ". . . we have no knowledge of what energy _is_."[1]

Nevertheless, the word "energy" does carry meaning for most everyone, and those meanings relate to some very important aspects of our lives. Part of the job of the science instructor is to illuminate and organize the popular and common meanings of science-related words like "energy", to relate them to modern scientific concepts, and, perhaps most important of all, to relate both to the individual's perceptions, experiences, and expectations; that is, to weave science into the various potential uses of knowledge by the individual.

Common notions about energy include these: It is something "needed" for every natural and mechanical process. Once used it can't be reused; that is, its "use" is an irreversible process. It is a cause of movement; it "makes things go". It "comes from energy sources", and those sources must be "conserved". Our bodies get their energy from energy stored in the food which we eat. The sun is the ultimate source of most of our energy; the sun allows life to exist on earth through its energy.

In fact, these notions conflict with or contradict much modern knowledge.

Scientific knowledge about energy includes: Energy is conserved; that is, there are no "sources" or "sinks" of energy, and nothing we can do can prevent its conservation. Energy comes in many different forms; and the difficulty in recognizing that it is conserved comes from the difficulty in finding all the ways of calculating the values of energy in its different forms. _The energy available for a specific human use of energy depends on many factors in the environment and on the purposes behind the use_; what we perceive as "energy" is, in reality, many different factors that we frequently tend not to differentiate.

The common notions about energy are not necessarily _wrong_. It is that they are not about energy alone, but rather about a confused mixture of many different phenomena and properties.

Erwin Schrödinger, in his essay "What is Life?"[2], made some points which are very pertinent to our perception of "energy". He identified energy as an irrelevant variable in metabolism. This fact is pertinent for three important reasons: (1) Our feeling for energy -- the meanings we generally associate with "energy" -- comes largely from metabolism and metabolic-like processes; food and fuel are our metaphors for "energy"; (2) The notion of irrelevant variable is one of the "formal operational" insights described by Jean Piaget: these are important to comprehending science and are the roots of great differences between people in how they conceptualize science; (3) An especially important variable in metabolism, and in all interactions between living organisms and their environments is entropy: this fact relates information -- and such phenomena as selection, probability, intelligence, and perception --- to life and distinguish life from non-life.

Schrodinger's point can be found in almost every "use of energy" we encounter. Consider the flow of energy from the sun to the earth, our "source of life". If the sun were to supply exactly that same amount of energy, but at room temperature of 70°F instead of at sun temperature (over 10,000°F), that energy would be completely useless to us. The energy itself is extraneous to our purposes. In this case it's something else we're after.

A wind can turn a windmill; energy gets transferred from the air molecules to the windmill blades. But it's not the energy or the motion in the wind that counts; it's the ordering of the motions. A howling hurricane is merely a slight ordering of the molecules; motions in one direction. Air molecules move at many hundreds of miles per hour even in a calm.

How much heat energy is "in" a kilowatt-hour of electricity? The textbook answer is 3413 BTU's, but if we use that kwh to run a heat pump we get much more heat. How much depends on factors in our environment, not the amount of energy alone. Even gasoline or heating oil can give us more heat if we use it to run a heat pump.

How much energy is necessary to operate an automobile? We can design a car that returns the energy put into climbing hills when we go down the hills. Energy for accelerating can be similarly be returned when we brake. All that's left is energy for overcoming friction and friction-like processes. These we can reduce greatly. There is no definite amount of "metabolic energy" necessary for running a car. (Herein lies the economy of ocean shipping.)

The same applies to heating a building. We might design a building with so much insulation - and it isn't all that much- that one person's body heat keeps the space warm on the coldest day. Then, maintaining temperatures as we wish them to be requires only moving insulation panels or valves on heat exchangers or the like, rather than burning fuel in furnaces.

The high temperature of the sun's rays, the ordering of the air molecules in a wind, friction, movement of heat with a heat pump or the leveling of temperatures as heat passes through the walls of our houses: these are all primarily *entropy* phenomena. That was Schrodinger's point; we eat food, breathe air, and eliminate wastes, not to replace "spent" atoms or calories, but to sweep away unavoidable and irreversible buildups of entropy. We take in low-entropy (ordered) molecules and eliminate high-entropy (disordered), "waste" molecules. The sun sends the earth a stream of low-entropy (per unit of energy) radiation, and the earth sends *just as much energy* in the form of high-entropy (per unit of energy) radiation to be absorbed by outer space. Energy is merely along for the ride. The essence of the process is in what happens to entropy. The physical property that belongs with our ideas of "energy" is more often negative entropy (ordering) than it is the energy of physics. Today, "Second Law efficiency" is replacing "First Law efficiency" in engineering practice.[3]

Furthermore, the essence of the process is not merely in some property in the input, the "energy in" some fuel perhaps. The *output*, the "waste", is just as important. If we had unlimited sources of fuels, we would discover that sweeping away of the wastes (entropy buildups) would become the limiting factor. "Heat pollution" is one such factor. We must coordinate many factors at once and not try to force all the information about some interaction into one "general factor".

Energy concepts are powerful concepts, but they must be properly used. In general, we must keep entire *systems* in mind and keep track of relationships and processes involved among the many factors. Energy and its conservation law is one of many useful tools in our knowledge of such systems.

(Another useful tool is to associate energy-related phenomena with specific systems: food goes with organisms; fuel with machines, metabolism with cells, free energy with chemical systems (aggregates of molecules), potential energy with *pairs* of objects, etc. Then we keep in mond both the relationships between the physics concepts and the relationships between the systems.)

ABSTRACT INFORMATION

What is entropy?

The word "energy" is familiar; "entropy is not. We feel that we understand energy much better than entropy. But the feeling is familiarity, not understanding. Entropy is much closer to our everyday experience, to our perceptions, to what distinguishes us as living organisms. Entropy is the easier to understand.

The scientific notion of energy split off from common ideas to develop into an extremely abstract concept. The original and more common notion of "energy"--something necessary to keep things going--is more related to entropy than to energy of modern science.

Entropy is one measure of "complexity". A major discovery of this century was that the thermodynamic concept of *entropy*, a notion that came from studies of steam engine efficiency, and information content, a notion that came from studies of telephone and other communication channels, are essentially the same thing. It is easy to generalize the two concepts into one.

Living organisms are especially characterized by their ability to act according to the outcome of the action. The out come determines the action. We can anticipate the outcome of our interactions with our environment. What we generally call "information" increases the probability that our expectations of our actions will actually happen. (The genius of modern behavioral psychology is in the recognition that the stimulus is an irrelevant variable in the determination of most behaviors of living organisms. Outcome determines most behavior. Living organisms "reach into" the future.[4,5])

Perhaps the most easily grasped notion of entropy (or information content) is as a number of selections. Whenever we interact with something we select from a number of possibilities. If we send a letter to one of 1000 post office boxes, we select one of the 1000. The post office box number -- three digits in this case -- selects the box with three selecting symbols. Each symbol selects from 10 equally probable possibilities. A gas, like the hot gas of exploded gasoline and air in an engine, has molecules with an enormous number of possible positions and velocities. If we wanted to indicate which one of the extraordinarily large number of combinations of positions and velocities of all the molecules that we have at some instant, we would need "selections", like the numbers of the post office box .. but many, many more.

These "selections" might be a numerical description (P.O. Box, e.g.), or a word description, or a photograph, or a set of nerve impulses in our optic nerve, or a television signal, or whatever. There are many kinds of representations of a thing. Some kind of representation is always necessary whenever we interact with that thing in the important way, so that our actions anticipate the outcome. Entropy is the number of selections when that "description" is complete.

If each selection is one out of n, and if W is the number of equally probable ways the thing might possibly be, then the number of selections S is given by $S = \log_n W$. (The base, n, is a kind of "unit", like ergs, joules, and BTU's are units of energy. Two common units of S are the decimal digit and the binary digit, the "bit". Different units differ, as usual, by an appropriate conversion factor.) This gives thermodynamic entropy ($S = k \ln W$, where k is Boltzmann's constant), and it gives information content of telephone signals or photographs.

The dot patterns of Fig. 1 vary from being perfectly ordered to being perfectly random. The amount of description for a highly regular pattern like Fig. 1a is essentially the same for any size of pattern.[6] For large numbers of dots the description is nearly zero "selections" per dot. The random pattern of Fig. 1d requires two numbers per dot; values for x and y, for example. How many digits in each number depends on the precision of measurement. If each dot is measured to one part in a thousand in either direction, then there are one million possible "ways" (positions) each dot may be. S = 6 (decimal digits: n = 10). In Figs. 1 b and 1c each dot is restricted to being near a lattice point of Fig. 1a. In 1b, the restriction of each dot is to 1/252 of the total area; in 1c to 1/63 of the total area.

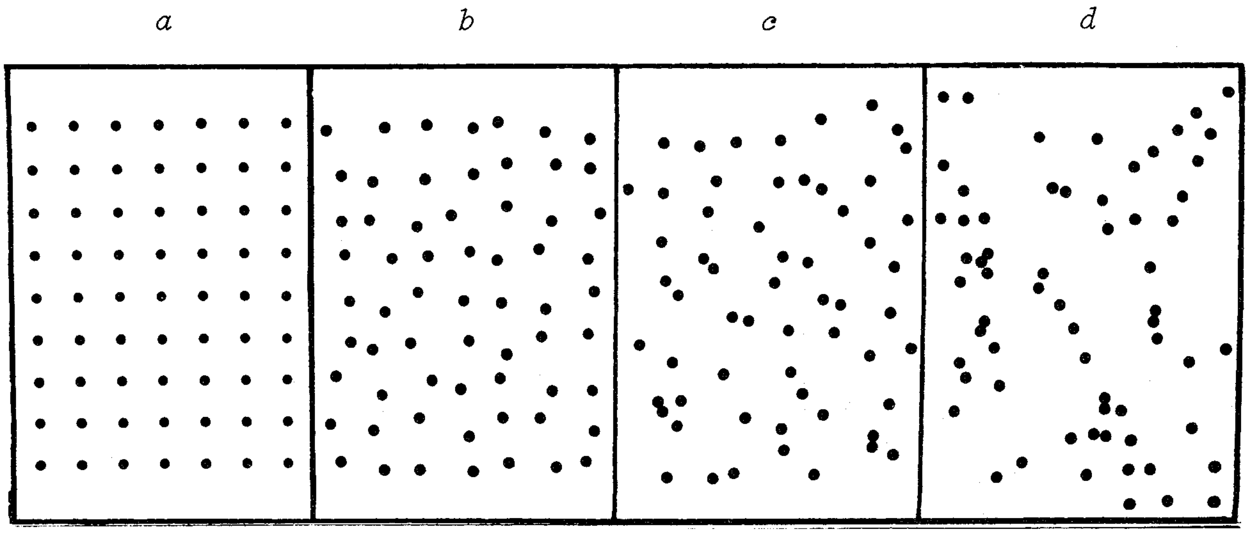

Figure 1

These dots could be maps (representations) of any number of things: positions of posts in a parking lot, positions and belocities (one each map dimension for either) or molecules in a gas, energy levels in a collection of molecules, frequency distributions of waves on a beach, etc.

We can get an intuitive feeling for many aspects of entropy by imagining them to represent posts in a parking lot, and that we are wandering blindly through them. We would quickly be able to choose our path contingent on the outcome of our choice with pattern 1a. We could not predict any outcomes with the pattern of 1d (except as we can remember encounters with the posts). The key to predictability here is repetition. Repetition is also what makes the entropy less than the maximum possible.

Patterns 1b and 1c would allow a greater probability of successful prediction than would pattern 1d (no predictability). The predictability of outcomes would be proportional to the repetitions or samenesses among the dots, more precisely to the correlations between the dots. This is the same thing as the amount of entropy that is less than the maximum possible. This is negative entropy or negentropy. It is also thermodynamic information.[7]

A pattern might be mostly random, but with one or more regions that are less than random. Figure 2 has two such "objects". Such regions are distinguishable from the background. We might be able to perceive them, a question of whether or not evolution has provided us with the perception. We could anticipate interactions we might have with those regions. If these patterns represented molecules of a gas (both positions and velocities) that distinguishability would soon vanish. The system would soon "come to equilibrium". Negentropy measures deviation from equilibrium.

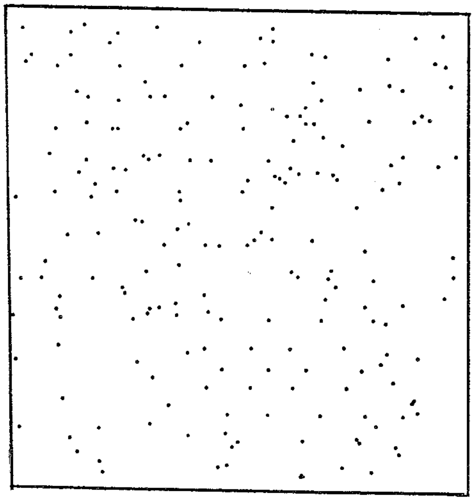

Figure 2

We should recognize that if we really are interacting with whatever the dots represent, say, lamp posts or molecules, and not merely talking about them or just thinking about them, then we must know both positions and motions for anticipated outcomes. "Stationary" posts means velocity is zero, but zero velocity is a value of velocity. Furthermore, precision of that zero value is important. At some level of precision, the posts are not stationary. They vibrate.

If we have all the data necessary to anticipate outcomes, then what at first appeared to be a potential for infinite information content (or entropy) is not. It looked as though we could arbitratily locate lamp posts or molecules as precisely as we wished; infinite information content because the "region of uncertainty" in then infinitesimally small. However, with the complete necessary description--position and velocity (acutally momentum = velocity x mass)--that uncertainty region has a definite area, Planck's constant, h = 6.63×10^{-34} joule-sec. This is Heisenberg's Uncertainty Principle.

"Perfect precision of position" can only be so much talk. When we do something, when we interact, we must know both position and momentum; consider wandering blindly among moving posts. Frequently a description of the Uncertainty Principle will speak of "having perject knowledge only of position" or "only of momentum" of an object. This description does not refer to our interacting with the object. It does not consider interaction in terms of anticipation. It speaks of absolutes rather than probabilities. It sees the Uncertainty Principle as a limitation, perhaps a limitation to be "overcome". It would lead to no definable value of entropy.

Using modern information theory we gain a more satisfactory understanding of entropy, and we tie that understanding to interactions of living organisms with their environments.

This approach can be extended greatly from the starting point given here.

PIAGET'S PUZZLES

What would it be like to have a different set of perceptions and other information skills?

Bees see polarization in light. Birds sense magnetic field direction. Insects see ultraviolet light and thus patterns in flowers and insect wings that are invisible to us. Some adults have eidetic imagery, an ability to mentally image great detail. A few people are colorblind; several different colorblindnesses exist. A few people are stereopsis blind; they can detect depth but not with stereoscopic vision (and they are virtually all unaware that they are stereopsis blind).

A child of 4 or 5 cannot conceive of one set of objects including another, larger set. When shown a set of two black wooden balls and ten white wooden balls and asked which there are more of, white balls or wooden balls, they reply that there are more white balls.

Polarization, the orientation of a magnetic field, images, color, stereoscopic depth, and inclusion sets are all negentropic features of the world. Ways of detecting or manipulating these features give living organisms certain advantages; that is, they help the organisms act in ways that can be contingent on the outcome. The development of a given information skill occurs over the millennia through evolution and also during the development of the individual organism.

The development of information skills, especially those skills uniquely human, is Jean Piaget's topic, "genetic epistemology". Epistemology is the study of how we know what we know. Genetics refers to biological development. The name is precisely descriptive.[8,9,10]

Piaget finds that skills related to abstraction begin to develop at about age 5-7, and he describes two kinds of such skills: (1) concrete operations (developed between ages 5 -11, approximately) dealing largely with reversibility, relationship, and classification; and (2) formal operations (developed after about age 11) dealing primarily with multiple parameters and propositions.

These developed skills are to be distinguished from what we usually think of as learning. The developed skills are genetically guided, and are more permanent than is "learning", more specifically physiological. They resemble color vision more than they resemble the learning of, say, multiplication tables. Piaget calls the concrete and formal operations "logic". This term almost universally connotes learned procedures of symbol (word or mathematical) manipulation. Piaget is refering to something else, for which we have no term because it is not widely familiar. Piaget's "operational logic" is much closer to the "logic" that occurs in the eye when one cone inhibits its neighbor in the process that enhances edge detection.[11] This is like "logic circuits" in a computer. It is a fairly permanent, "wired in"logic. "Learned" logic is "extinguishable".

Stereoscopic vision and Piaget's operations have almost exactly the same characteristics; (a) development at a critical age; if missed then, then not developed at all (stereopsis develops at several weeks of age[12]); (b) irreversibly developed, except for possible nerve damage; (c) developed through discrepancies in observations or expectations: "teaching" and imitation have little or no influence; (d) cause something to be "obvious" -- or else must be accepted "on authority", or through alternative "calculations", or not be accepted at all. For example, a totally colorblind person might learn from other people the colors of every object he encounters, or he may learn how to infer color from spectrographic analysis and a diffraction grating he carries around, or he may, if he is quite bright and really studies color and other people's behavior carefully, come to the conclusion that "color" is a myth. (Note that "normal" human color is only a three-componeneted shadow of an infinite-componented reality. We cannot, for example, differentiate mixtures of wavelengths of light as we can of sound with our hearing. An extension of human vision would be the complete differentiation of visible wavelengths; a reciprocal extension of human hearing would be image formation from sound waves.)

The most important part to scientists of Piaget's work is the formal operations. Here are the most advanced information-related skills that have been studied. When they are understood, they can be seen to play a central role in the conceptualization of science--both for the scientist who discovers the concept and for later learners. They are not fully developed, or they are not readily used by a majority of adults.[13,14] They, therefore, are important to differences in ways different people conceptualize science. They are, in all probability, not well-represented in IQ concepts of intelligence.[15] IQ focuses more on pre-operational (before age 5-7), language skill developments.

Piaget describes two different kinds of formal operational insights; he calls these "lattices" and "groups." We have already seen some lattice insights. The extraneous variable relationship of energy to metabolism and stimulus to (operant) behavior are lattice relationships. The flaw in the statement "Energy is the capacity to do work" can be seen with lattice insights: The "is" carries two mutually reciptocal implications; The capacity to do work implies energy, which is correct, and energy implies capacity to do work, which is not correct. From a non-formal operational viewpoint these distinctions do not exist, except possibly as rote-memorized procedures.

The following puzzle can demonstrate adult differences in clarity of a related lattice insight, the distinction between an implication and its reciprocal (which includes the often confused distinction between necessity and sufficiency):

> In a set of cards each card has a number on one side and a letter on the other. Four cards are lying on a table. They show "A", "B", "4", and "5". Someone suggests the hypothesis: *If a card has a consonant on one side then it has an even number on the other side.* The puzzle is to determine which cards must be turned over to test the hypothesis. No card is to be turned over unless necessary to test the hypothesis.[16,17]

Occasionally someone sees the answer to this problem exceedingly clearly, as though looking at the color of a perfectly clear blue sky through a freshly washed picture window. More often the solution is seen after some straining and mistakes, more like looking at the sky through a multi-faceted, stained glass window. Sometimes learned logic, as one learns in a college course, is resorted to: not a Piagetian operational route, but more analogous to analyzing light with a spectroscope. Frequently, even explanations fail to bring understanding: The statement of the problem is often found at fault, in the same sense that a totally colorblind person would find fault with the question, "Is that glow red or green?"

Lattice insight leads to separation of variables, elimination of contradiction, recognition of extraneous or irrelevant variables, a sense of "all else being equal." These we have seen to be important in untangling the parameters in the popular concept of "energy". Lattice insight can take the simpler relationships of "either.. or ..", "both..and.." and "neither..nor.." and perceive finer, more intricate distinctions when appropriate. Among these more complex distinctions are, for example, implication, non-implication, reciprocal implication, mutual exclusion, and/or, equivalence, etc.

Piaget's group insights can be seen in the Golden Rule. A person seeing clearly with formal operational group insight sees the Golden Rule as a logical imperative, not merely as a learned "should". Young children may memorize it..but it frequently comes out "Do unto others as they would do unto you", a concrete operational version. Lawrence Kohlberg has investigated these matters to great depth.[13,18]

Group insights lead to a feeling for, not just memorized procedures for, ratios, probability, coordinated, multiple, reversible actions, such as can be seen on a beam balance, especially if the pans can be moved with respect to the fulcrum. (The "group" is the group of coordinated possible actions and negations of actions.)

Other formal operational insights are the sensing of metaphor, the imagining of extrapolations to unattainable limits, and correlations.

I would suggest an even less used set of formal operations important to modern science. These derive from operations important to modern science. These derive from operations upon operations and lead to complementarity concepts. For example, "Energy and mass are merely different expressions of the same thing" is Einstein's way of putting the concept behind $E = mc^2$. That does not mean, as is often suggested, that one can be "converted to" the other; a concrete operational relationship, the "thing" being either energy **or** mass. Energy and mass are distinct from one viewpoint (how we observe them) but the same thing from another viewpoint (like two sides of the same coin). An increase in one must be accompanied by an increase in the other. (The usual misconception would predict a decrease.) Position and momentum are a compoementarity. So are the components of a vector, tensor, complex number, or quaternion. Complementarity frequently leads to a conceptual whole greater than a mere sum of the parts.

Multi-componented measures (vectors, tensors, etc.) are numerical manifestations of formal operations. Scalar measure, as most often conceived, is concrete operational. Scalar measure is characterized by transitive sets[19], uniquely definable rank orders (like military "pecking order") and comparatives (like "better" or "larger", etc.). Scalar measure is from the realm of pre-adolescent childhood, but is almost universally the present cultural limit of "measure" concepts. Multi-componented measures reflect the adolescent developments (formal operations) and carry situation dependence, multi-dimensionality, multiply coordinated parameters, etc. These more complex measures are not generally transitive, and do not allow rank order or comparative relationships by them. The "value" or "quality" of a human being is multi-componented. "All men are created equal" is then a logical imperative because to say one man "is superior to" another has no particular meaning. It's a statement about the observer's preference not about the observed's "value." Among non-scalar measurable entities are stress and strain in solids, intelligence, teaching effectiveness, economic activity (Vassily Leontief's Nobel prize), voting preferences on some issue[20] (kenneth Arrow's Nobel prize), factor analytic correlations.[21] Non-scalar measure is the rule, not the exception.

One clue to operational barriers in a student's learning of science--and I suggest this as a defining characteristic of a "Piagetian phenomenon"--is that as a student's trouble point is ferreted out, the point becomes more and more "obvious" to the instructor (and probably to a few students) but more and more obscure to the learner. A student once asked me, after over an hour of trying to find his difficulty, "Why do you seem to think that the ladder has the same length when it lies flat on the ground as it had when it was leaning against the wall?" This was a failure at concrete operations.[13,14,22]

Work on Piaget operations has only begun. We need to develop experiences with these phenomena so that we can approach theorizing about them from a base of experience and observation. (A scientific "theory" is not unobservable hypothesis, but rather organization of the best observations.

The word "theory" has the same roots as "theater", a place where we observe. The extreme persistence of "hypothesis" as the emaning of "theory" suggests "Piagetian phenomena in action").

"I INTERACT WITH THE WORLD"

What is science?

An almost magical source of needs and desires? A search for the few fundamental principles from which can be derived descriptions, explanations, and predictions of everything in the universe? An escape from the more human aspects of life? These share something. They all shun complexity in one way or another. They avoid the information necessities that can lead to effective interactions with the world. Asserting that the simple regularities of the motions in the sky can represent the complexities of human life--astrology, that is--also shares this flaw.

Science is, above all, a set of refinements in human interaction with the world. The chief characteristic of that interaction is variability of behavior in response to variations in the environment. Human excellence is coping with complexity.

Science can be seen as an enhancement of human ability to cope with complexity, a step toward evolutionary advance in the direction of generalized adaptability. However, scientific laws are expressions of sameness of behavior regardless of variations in the environment. Science searches for simplicity.

This relationship often seems to imply a kind of antagonism between science and humanness. There is no such antagonism. This relationship between science and humanness, between the simple and the complex, is the relationship of complementarity. As in the dot patterns of Figs. 1 and 2, we cope with complexity by finding imbedded "simplicity," by finding regularities, laws, sameness, correlations.

The search for some ultimate simplicity led to the scientific paring away of the original meanings of the word "energy": the necessity we, as living beings, feel and experience in food, and in modern times in fuel for engines. The energy of science is one of the grandest simplicities of all: a highly abstract entity, known to us only through mathematical formulas, which has a sameness of value no matter what happens (as long as all things affected are taken into account). In stripping away the complexities of the original notion, science stripped away most relationships to living organisms. The necessity we feel, and call "energy", is gone.

What we today call entropy was the essence in that original notion of "energy." Entropy is one measure of complexity. Science, in the search for simplicity, had stripped away the concepts related to entropy.

An understanding of entropy (information) shows that another necessity, besides the energy requirements, is present in our interactions with the world. We cannot raise a weight without supplying sufficient energy; we cannot anticipate the future without sufficient information. Either necessity, the simple energy or the complex information, is insufficient. The essence of life and the excellence of human beings lies in the realm of complexity and information. The means of coping with complexity lie in the many regularities and laws of the universe. Like energy and mass these are not a mutual exclusion, an "either..or.."; they are as inseparable as the sides of a sheet of paper, a complementarity.

The organization of the sciences into physics, chemistry, biology, psychology, sociology, etc. follows the inclusion-hierarchy of systems; particle - atom - molecule - cell organ - organism - society - ecosystem - universe. This is an organization of knowledge designed to isolate and compartmentalize. It especially isolates knowledge from human interactions with environment, putting human matters "in their place" in the hierarchy. This organization is well-suited to discovering simplicity.

We need a complementary (not a substitute) organization that ties knowledge together. Most science has tended to deemphasize relationships between academic disciplines; we especially need an organization that emphasizes those relationships. And we especially need an organization that relates knowledge to human coping with the complexities of the world.

Let's look at a few natural inquiries stemming from this way of looking at knowledge. Fundamental questions about perception include: What do our perceptions tell us of the world? What do they exclude? How do we know that they do? How can we extend our perceptions? Fundamental questions about decision relate to authority (decision by others) and autonomy (decision by self): When and how do we use experts? Evaluate experts? When do we cooperate to enhance decision effectiveness? To avoid making one's own decisions?

What our perceptions tell us of the world must be examined from the viewpoint of the physicist who specializes in light, optics, sound, interactions of light with matter, image formation, perhaps electron optics, etc. It must be studied by the physiologist who specializes in the functioning of the retina, of the lens of the eye, of the brain, of the sense of touch, etc. And by the chemist who specializes in the light sensitive molecules such as retinene, carotene, etc. And by the anthropologist who specializes in how different cultures regard perception, train people's sensitivities to potentials of perception, etc. And by the artist who specializes in the abstract essences of communications by image, sound, and meanings. And by the philosopher who specializes in epistemology.

Alternatively the topic might be examined by a specialist in what our perceptions tell us of the world, or by a person who specializes in both chemistry and perception, or by a person who specializes in finding, learning and using knowledge. The present clusters of knowledge we call "disciplinary specialties" are not the only clusters of knowledge possible for a person. Nor are they well-suited for the kind of topic that belongs in this "I interact with the world" frame of reference.

Central to these human-interaction topics is the topic of personal development and integration, the "I" of "I interact with the world." This includes Piaget's genetic epistemology. It includes the new topic of ethology[23] It includes the development of values and value systems.

This suggestion is for a set of studies, curricula, and "disciplines" that fill in certain gaps. New disciplines have sprung up to meet new needs: agricultural science, materials science, schools of education. These create specialists. Nothing has yet sprung up that fits knowledge to the non-specialist. How do tensor analysis, entropy, factor analysis, Piaget operations, operant conditioning, input-output analysis, micro-and macro-economics, non-parametric statistics, feedback principles, systems hierarchies, etc. relate not so much to the specialities for which they were developed, but rather to the general process of human living? Even knowledge about learning processes, the nominal profession of every college instructor, is rarely disseminated to, or sought by, instructors outside the specialties of educational psychology and education. Academia remains territorial.

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A New Approach to Organic Chemistry: The Two Cycle Approach

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Presented to a General Session of the Forty-Fourth Two Year College Chemistry Conference, Manor Junior College, Philadelphia, Pennsylvania, April 5, 1975.

Anyone who has taught sophomore organic chemistry and the accompanying laboratory recognizes several major problems in the teaching, as well as in learning by the student, of organic chemistry in the classical manner. Specifically, these are:

1. The tremendous bulk of organic chemical information available;
2. The inability of introducing significant organic chemical reactions early in the first semester (which in turn severely limits the type of experiments that can be used in the concurrent first semester laboratory);
3. Too many "look-ahead" references to the structure and chemical properties of functions yet to be encountered; and
4. An insufficient amount of discussion of comparative reactivity of various functions that undergo similar reactions.

In an attempt to aleviate these problems, Professor C.D. Gutsche of Washington University and I have developed a two-cycle approach to the teaching of organic chemistry (Fundamentals of Organic Chemistry", Prentice-Hall., January, 1975).

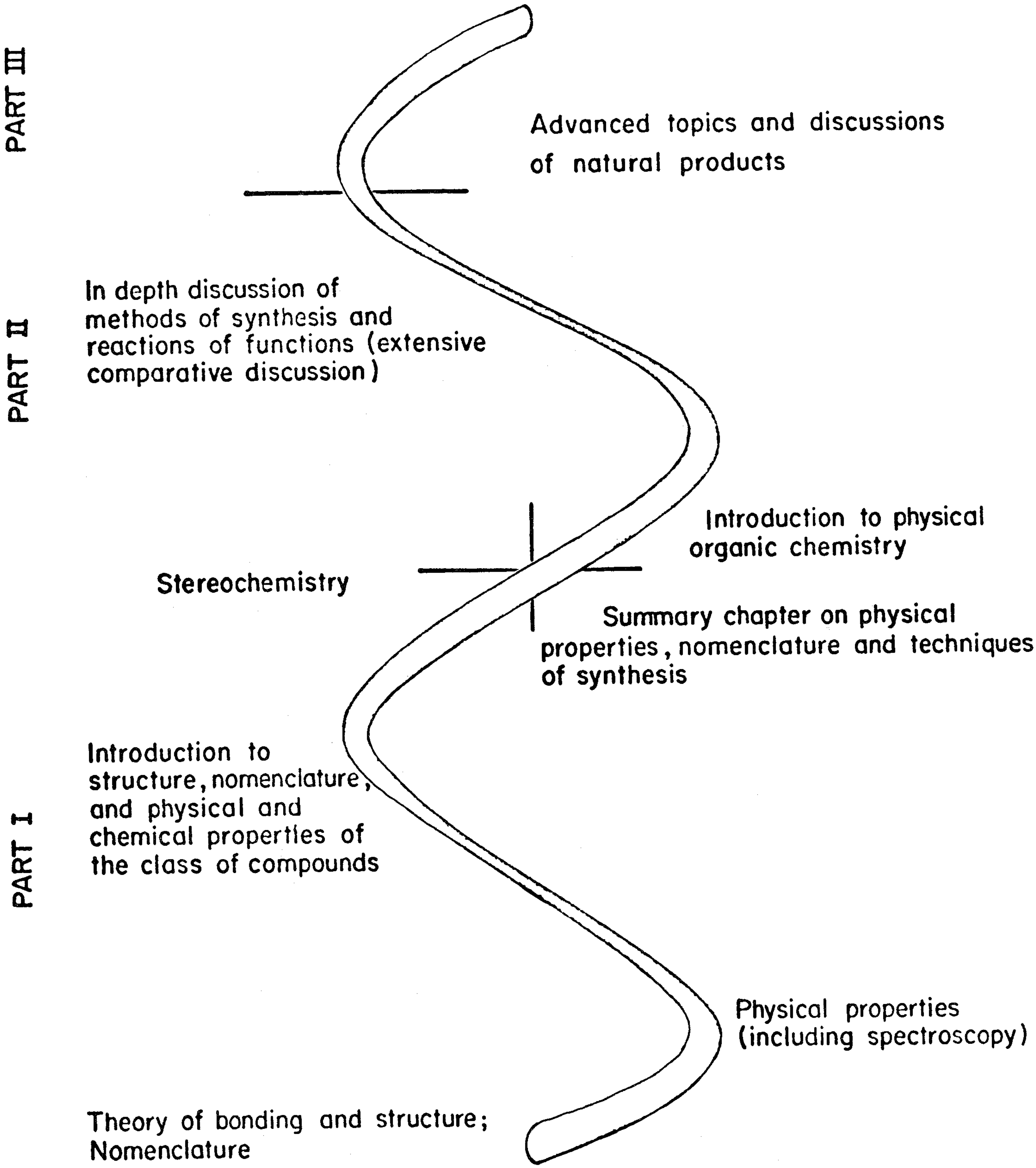
In the two-cycle approach we make two complete tours through organic chemistry (see Fig. 1). The first cycle represents the first semester of the course and opens with discussions of the theory of bonding, structure, and physical properties followed by a sequence of chapters on the functional classes which discuss the bonding, structure, nomenclature, comparative physical properties, general chemical reactions, and individual compounds of particular interest and utility. The discussion of the chemistry of the functions is, in general, restricted to general addition, elimination, and substitution reactions, trying to avoid "look-ahead" references to functions not yet encountered. The first cycle ends with a comprehensive discussion of the stereochemical properties of molecules (the concept of the chiral carbon, enantiomers and diastereomers were introduced earlier in Chapter 3). The placement of this chapter at the end of the first cycle allows for a more meaningful discussion of stereochemistry as the student will have been introduced to the structure of all of the functional classes of compounds. Part I represents a complete, low-level, one semester organic course.

The second tour through organic chemistry comprises the second semester. Considerable flexibility in the choice of topics and the level of discussion is possible; i. ., the material to be covered can be tailored to the needs of the particular class. The first chapter of Part II is an in-depth discussion of the techniques of studying reactions (physical organic chemistry) and the effects of structure and environment (solvent and salt effects) on reaction rate. This chapter is recommended for chemistry majors, but may be omitted with premedical and/or biologically oriented students. Chapters 21-31 discuss in detail the synthesis and reactions of the functions, as well as correlations of reactivity of the various functions in similar reactions.

Part III contains chapters devoted to special advanced topics and discussions of the chemistry of biologically derived classes of compounds. These latter chapters are ideally suited for the premedical and/or biologically oriented students.

Our experience has shown that the two-cycle approach greatly alleviates the problems enumerated earlier. Specifically, it introduces reactions earlier, avoids "look-ahead" references, provides greater repetition, and allows for more extensive comparative discussions of reactions and reactivity which leads to a better understanding of reactions and less memorization. In addition, we have found it possible to incorporate more meaningful experiments in the concurrent laboratory course earlier in the first semester.

Two-Cycle Approach



Audio/Visual Programs for Laboratory Skills

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Presented to a General Session of the Forty-Fifth, Two Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, May 29, 1975.

In an attempt to run a physical chemistry laboratory class with a minimum of problems and to free the instructor from the role of describing simple equipment and its operation, a series of audio-visual programs have been prepared for the direct use of the students.

I do not profess to be introducing a unique idea but through this presentation I can perhaps give others the benefit of my experience in developing visual material for specific lab equipment operation.

It may be helpful before describing the program to explain briefly the environment in which the programs are used. The physical chemistry lab is a third semester course for chemical technologists and class sizes for the lab are usually no greater than twelve but have been as high as twenty students. A few slides taken in the lab will give you some idea of the type of equipment we are working with. Students normally work in pairs and rotate through the experiments on a weekly or bi-weekly basis depending on the complexity of the experiment. Before starting a new lab the student must do a pre-lab write-up, including some theoretical background of the experiment, data tables, and in some cases information on equipment operation.

In the past the operation of basic pieces of equipment such as constant temperature controllers, differential thermometers, density balances, refractometers, etc., had to be explained by the instructor when the lab began. Written instructions have been tried but students generally find these unsuitable unless the equipment is in front of them and even then it has serious limitations. For example, in trying to explain how to set s differential thermometer, the instructions make very little sense unless the student can actually see the different positions of the mercury column which he cannot do until he actually starts to manipulate the thermometer. By then it may be too late as witnessed by the fact that three differential thermometers were broken in my lab in a two year period.

One alternative approach is the one devised here where a series of 35 mm slides are prepared showing the equipment in all possible configurations during its operation. An audio tape is then prepared describing the entire operation in the same way it would be done if I was explaining the process in person. The slides and tape are then synchronized and packaged for presentation on a Caramate slide projection unit or made into a filmstrip and presented on a Bell & Howell filmosound viewer. In addition to freeing the lab instructor from explaining the basic operations in class, the audio/visual program thus prepared is available to the student at his convenience, so that better preparation can be achieved before the student enters the lab and also he can review the instructions at any time during the semester. This latter point is important in my lab because we have a practical exam at the end of the semester and students usually like to review their labs before the exam.

PREPARATION

A number of interesting slide presentations, films, or video tapes have been presented in the past for lab instructions and other purposes but in my opinion they always have two severe drawbacks, they are time consuming to prepare, often requiring two or three people taking several days to make a short film for example, and they are sometimes difficult to edit or revise. The approach taken in the "caramate" program simplifies both problems considerably.

In the preparation of slides, one reasonably experienced photographer can take a series of slides shooting all angles, positions, close-ups, et. which are required at a very modest cost. For most programs the initial slide package may consist of fifty to seventy-five slides i.e., two to three roles of film. The slides are sorted on a slide viewer and a written script is prepared as the slides are placed in sequence. Usually at this stage a number of other views of the equipment or special slides may be suggested which were not taken the first time so a second shooting session is arranged. When all the slides are prepared the commentary is finished and taped. After taping,the slides are arranged in the "Caramate" slide tray and the audio tape is placed in a tape recorder having a pulsing unit.

While the tape is played, the slides are manually advanced in proper synchronization and simultaneously a pulse is put on the tape. At the end, the pulsed tape can be put into the caramate unit and synchronization of audio and visual material will be automatic if they are started in the right place. After the students have used the program additional editing can be done easily for the slides and with a little more difficulty for the audio tape, but certainly with less work than trying to edit film or video.

After the program is considered finalized, transfer to a film loop is a useful step if you can also purchase a film-loop reading unit, such as the Bell & Howell. The two advantages of this are: compactness - the cartridge for the loop is much smaller than the slide tray, and total automatic synchronization - tape and film loop move forward or backward together keeping synchronization at all times.

Feedback from the students on the effectiveness of these programs is very sparse at the present time since only two programs have been in operation this year. Verbal responses from the students have been encouraging, however, and they have asked to review the programs a number of times. The only criticism received referred to the difficulty in following the logic of the theory behind the density balance. This I believe in part is due to the students' lack of experience in using the programs. For example, students initially listened to the program in a passive role but later on decided to make notes on certain points. It may be desirable to issue the student with a written text of the audio presentation or perhaps a summary of theoretical points. This is one aspect of the program which will be investigated further for the next academic year.

Water Pollution Investiations Based Upon EPA Standards

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Presented as a Hands On Workshop at the Forty-Fourth,Two Year College Chemistry Conference, Manor Junior College, Philadelphia, Pennsylvania, April 4, 1975.

A. NITRATES TOXICITY IN HUMANS AND ANIMALS

Nitrate toxicity in humans is primarily limited to infants less than 3 months old. Infants are more susceptible to the nitrate concentration in water because water makes up a larger portion of their diet. Nitrate poisoning in infants results in a condition called methemoglobinemia which affects the hemoglobin's ability to carry oxygen to tissue.

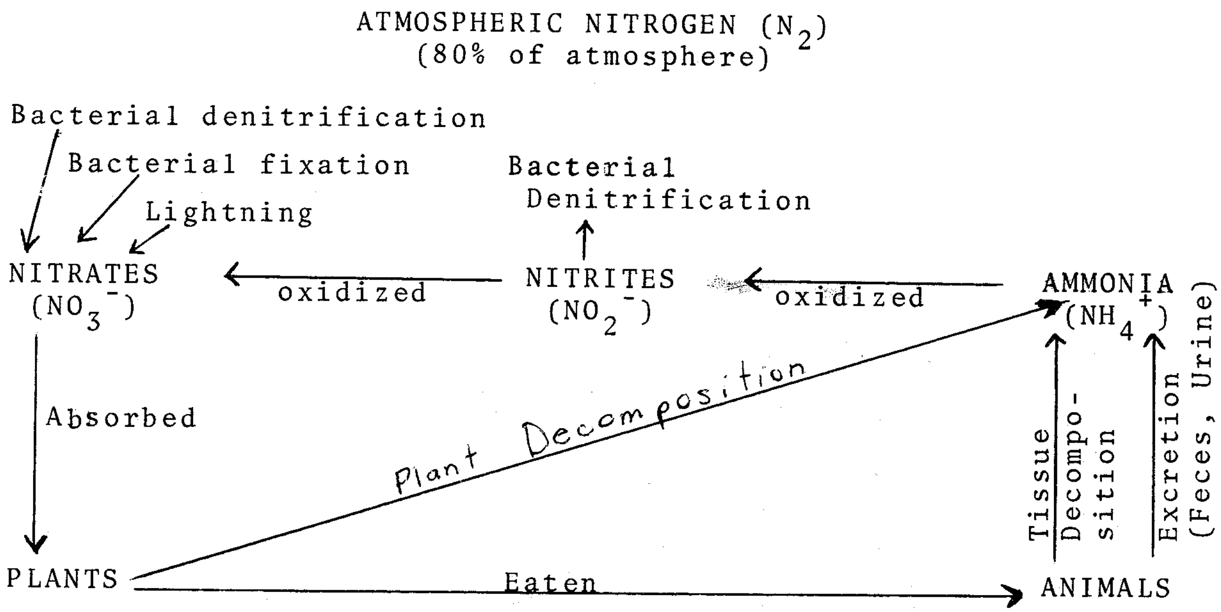
High nitrate concentrations in the diet of animals, particularly ruminants (cattle and sheep), may cause the following symptoms; labored breathing, tremors, collapse, bluish color of the mucous membranes, and very dark blood.

Animals seem to be able to adapt to high nitrate concentrations in the feed, if applied over a period of time. However, in one shot exposures it was found that the LD_{50} (lethal dosage for 50% kill) for ruminants was 75 mg/kg body weight when nitrates were administered as a drench and about 255 mg/kg of body weight when nitrates were sprayed on forage or feed. The figures imply a water consumption of 3 or 4 times the dry matter intake. The amount of nitrates to be tolerated in the water should be approximately one-fourth the dry matter intake which results in the following recommended limit 300 pp. for nitrate and 100 pp. for nitrite.

B. WHERE DO NITRATES ORIGINATE?

Nitrates are soluble in water and readily absorbed by the plants. Since nitrogen is an essential plant nutrient and is usually deficient in cultivated soils, nitrogen is added in various types of fertilizers such as manures, organic fertilizers, anhydrous ammonia, urea, ammonia sulfate, ammonia nitrate, and sodium nitrate. The end product of adding different fertilizers, as mentioned above, depend upon chemical reactions within the soil to convert the various forms of nitrogen to nitrates. The plants readily assimilate nitrates through the root systems. Once inside the plants the nitrates are first converted into nitrites ⟶ ammonia ⟶ amines ⟶ protein.

Brief description of the Nitrogen Cycle:



One of the overlying problems with adding fertilizers is to add enough nitrogen to produce higher yields without getting toxic amounts in the crops and the water. If excessive nitrates are not utilized by the plants, the nitrates can readily enter into the water. Some of the factors which affect the nitrate content in water in ponds, wells, and streams are as follows:

1. Nature of the soil surface
2. Amount of rainfall
3. pH of soil
4. Proximity of feed lots, septic systems, sewage treatment plants
5. Porosity of soil
6. Amount of available nitrogen in soil.

C. EPA STANDARDS FOR DRINKING WATER

The maximum acceptable concentration of Nitrate Nitrogen in raw water used for drinking is 10 ppm.

The maximum acceptable concentration of Nitrite Nitrogen in raw water used for drinking is 1.0 ppm.

D. DESCRIPTION OF METHOD USED FOR DETERMINING NITRATE NITROGEN IN WATER

The initial step is to reduce the nitrates to nitrites by using a zinc reduction. The nitrites (those originally present plus the reduced nitrates) are then reacted with sulfanilamide to form the dizao compound which is then coupled in an acid solution (pH 2.0 - 2.5) with N-1 naphtylethylene diamine dihycrochloride to form the azo dye. The azo values are readily obtain-able by carrying out the procedure - first with, and then without the zinc reduction.

Individualized Instructions in One-Year Chemistry Department

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Presented to a Symposium - Approaches to General Chemistry Instruction at the Forty-Fifth, Two Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, May 29, 1975.

Most of us who teach in two-year colleges realize that student variability in background, ability and motivation constitutes our greatest challenge as instructors. Each of us approaches this problem in a way consistent with our interests, abilities and resources. This last item, resources, especially with regard to time and money can be a difficult obstacle to instructional development in a small college. Out of the many promising alternatives for improving chemistry instruction, what can or should be done in a one-man department? I will present here one answer to the question.

Students enter the chemistry course at Lord Fairfax Community College with no screening or selection, other than the desire or program requirement for chemistry. They often have little or no background in chemistry and in many cases are afraid of the course (an "I'll fail anyway" attitude). The college has not offered a preparatory or developmental course for a number of reasons: lack of funds for additional staff; if offered first quarter, students could not start the normal sequence until the next fall; no summer funds are available; and for various reasons it is difficult to get students to take a "remedial course". In addition, I have seen little correlation with success in the course and a student's having taken high school chemistry.

A small college has distinct opportunities for close student-teacher interaction which I believe should be capitalized upon rather than discarded to implement a type of instruction which grew out of a multi-person department with many students. Having utilized the traditional format in the past, I sought to retain the small college's advantages, but improve instruction based on the following ideas. I felt a desire to break through a lock-stepped and professor defined pace for learning course material. There is also a principle of behavior which a colleague expressed: "Reinforced independent behavior is a more effective way of learning than the 'student as a sponge' principle". I also believe that the function of the "professor" is not to profess, but to teach by instructional design and evaluation, individual interaction with students, coordinating and guiding student effort, and inspiration or motivation. One way to provide the latter is by the traditional lecture.

These ideas led to the goals that a student would: (1) learn to use educational objectives as a means to direct their own learning; (2) learn to use a variety of media such as texts, films, programmed materials, slide-tape programs and the "consultant in residence" (the instructor) as a means of learning; (3) recognize learning as an on-going individual process which is not confined to a classroom and, of course (4) learn a body of knowledge and skills in chemistry that will serve as a building block for later work in his own field.

My approach was to provide some individualization of learning method, student pacing, and testing. To minimize my own work load and provide a basic source for the student, I selected what I felt would continue to be a good text for a number of years.[1] I deliberately avoided the commercially available audio-tutorial courses because of equipment expense, lack of additional instructors or tutors, and what I felt would be loss of the student-teacher closeness which already existed.[2] I also found having a study guide for the text with usable learning objectives a definite advantage.[3]

The course content is divided into 22 units (by quarter system: 7,8,7) coinciding with chapters of the text. The students are told that the study guide objectives should be considered their course objectives. They are given solutions to all of the problems in the text, a schedule of dates when units would be introduced in the classroom, a sheet describing the testing procedure, and a list of "Additional or Alternative Learning Sources" available in our Learning Resources Center. For each of the 22 units, this list contains an itemization of commercially produced tapes, slipe-tape programs, programmed text chapters, films, reference books, other texts and any other resources that I could think of which we had available. Attendance is optional at all classes.

The first class hour of each week is devoted to motivation and guidance in difficult areas. The second and third meetings are used to deal with individual student problems or to give mini-lectures on specific topics requested by the students. One of the Chem-Study Films is sometimes shown to stimulate discussions. For some students class hours turn into very personal times, for others this type of input does not seem to be necessary. I even have three very good stu--dents who hold part-time jobs during these scheduled hours.

When a student feels prepared on a unit, he may take a test in our Learning Resources Center at any time from 8:00 a.m. to 10:00 p.m. five days a week. A sheet of carbon paper is inserted between two mimeographed copies of the test so that the student produces two answer sheets. When finished the student submits his original sheet, is given the detailed solutions to the test, grades the carbon-copy in front of our Learning Resources personnel, then turns in all materials when he leaves. This provides him with immediate feedback without the necessity of a trained tutor. Each morning I pick up all the tests, check and record grades, and file all the tests. A student may come to me to go over his filed tests at any time. If he is satisfied with his score, he proceeds to the next unit. If not, he may retest the next day with no penalty.

After the first quarter, I established cut-off dates on the availability of tests. This was done to overcome student inertia and was also requested by many of the students. These cut-off dates for each unit test are at the end of the third week after the introduction of that unit. When a student has taken at least one test for each unit he may, during a one to two week period at the end of the quarter, retest on any unit. The student must therefore keep up the pace in order to retest or review at the end of the quarter.

I have written three tests for each unit and made a great attempt to insure that they are all equivalent. Most students seem to make a sincere attempt at one test (their first test may be any of the three, randomly selected), and if they do not do well, review what they did not understand. In this way the test becomes learning devices. A few students take the first test with very little studying and use this as a basis for the study in that unit. This amounts to using one of the tests as a pretest to check their knowledge of a unit before studying it. I believe there are definite benefits in offering at least three versions of each test. There is a general removal of threat, fear and dilution of emotional stress on students. This probably has a positive affective response in the student's feelings about chemistry which should also influence his performance on cognitive objectives. It seems to be quite important to the students to know I personally wrote all the tests, not some vague "they". In order to avoid conditioning the student to only one way of thinking, the test questions follow no particular format. Where multiple-choice seemed a good format it was used, and in some cases short discussion questions were asked. All numerical problems have space for computation, which must be shown to receive credit.

Percentage grades from the student's best grade on each unit are averaged. These comprise 70% of his final grade, the remainder being a conventionally graded laboratory. I did not use a unit mastery concept (at the 90% or 100% level) since I felt all students should learn at least a minimal amount about all the course topics. I also believe that for the use many students will make of their chemistry course, mastery of all the concepts is not necessary; passing at some lower level is perfectly acceptable for those students. Since our college still requires a traditional grading scale, those students with higher level mastery will reflect this in their grades.

The advantages to this system are: (1) better students can proceed at more rapid pace (they often seem to compete with each other); (2) poor students are not threatened by chemistry, but view it as a situation where they <u>can</u> learn; (3) student-teacher interaction is actually enhanced, particularly when they come to my office to go over their file of tests; (4) the testing situation is less threatening by allowing the student to concentrate on learning material, not just "cramming for a test"; (5) it allows me to quickly identify students with problems, contact them and attempt a solution; (6) although the initial time investment by the instructor is high, this is not so great later, and the monetary investment is no more than the traditional procedure, (the Learning Resources personnel who administer the tests have no training in chemistry, any librarian or secretary can perform this function); (7) this system is flexible and changeable as new ideas, materials or types of students appear. With no money invested there is no "previous investment" to consider; and (8) it also fosters student independence and initiative.

Results and evlauation of the course are generally very encouraging. During the year previous to offering the course in this fashion, I had discussed various aspects of what I planned to do with many students and faculty at the college. This may have been at least partly responsible for an enrollment increase from 17 in the fall '73 to 37 in the fall of '74. The interest of these additional students was not superficial, since 89% of the 37 students enrolled completed the second quarter. This compares to 82% of the 17 students in the traditional course. This high retention rate is in contrast to the high drop rate of many Keller Plan Courses.[4] The grade distribution however, was similar to what has been reported for the Keller Plan (or P.S.I.) type of course: 52%-A, 27%-B, and 6%-C. These grades contrast with those given the previous year in my course using the traditional method: 12%-A, 35%-B, 35%-C. When asked the question, "Considering that the primary goal of this course is to enable you to learn chemistry, how would you rate this method of instruction?", the students rated it a 6 on a scale of 7 (Outstanding) to 1 (Very Poor).

I am convinced that this method of instruction in my department has resulted in considerably greater student and teacher satisfaction and in greater student learning. As a result of my experience with this course, I am planning to convert our organic chemistry course to a similar method.

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Consumer Chemistry: A Bridge Between Student Interest and Motivations

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Presented to a Symposium on Consumer Chemistry at the Forty-Fifth, Two Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, May 29, 1975.

ABSTRACT: Three items are to be considered:

1. Why "Consumer Chemistry" is an area to cover in a freshman chemistry course.
2. Some examples of useful topics in this area.
3. How to generate new topics in this area to cover newsworthy items, regional problems, and newer developments in this area.

There have been two sides to the study of nature almost as far back as we can trace the history of such efforts; the purely intellectual pursuit of "truth" and the efforts to develop practical knowledge.

To many chemistry teachers, the inclusion of "Consumer Chemistry" in a freshman chemistry course is simply another example of the growing strength of the anti-intellectual movement of our times. Most political leaders have exerted considerable pressure on the scientific community to make its work more relevant to the daily lives of the citizens at large. One is often reminded of the anguished remarks of Bertolt Brecht's Galileo,

> *"Not all is great, that a great man does and Galileo ate well with pleasure ..."*

The community pressures (be they ever so subtle) are almost universally found to ask some justification for the apparently care-free life of the scientist.

Be this as it may, the teaching scientist in a community dedicated to nearly universal access to higher education is faced with an incredibly difficult problem when the majority of the students have only a peripheral interest in pure science. They also persevere in this no matter how often we <u>tell</u> them how important science can be in their daily lives. It is, in fact, necessary to <u>show</u> them how crucially it impringes on practically all of their daily activities. Students can be as parsimonious with their efforts as politicians are with their funds, unless we provide them with reasons to study which are valid for <u>them</u> (not us). We are fortunate today that there are so many scientists, because the scientific basis of so many practical things is now understood and used as a basis for improvements. A young woman who spends most of her time in chemistry lecture flirting with her handsome neighbors will probably become very attentive when a discussion of the chemistry of birth control pills or cosmetics begins. I think that this was appreciated much more fully by the writers of chemistry textbooks prior to about 1940 or 1950. In most of the older textbooks you will find innumerable places where an attempt is made to tie chemical information to daily life.

It is probably true that at least 50% of the students in any freshman chemistry class are there for reasons other than a burning desire to learn chemistry. However, every time you are able to tie the chemistry you are teaching to an immediate personal experience, their interest will increase and they will learn more about that item than otherwise! And what, may we ask, is our task? To give them something in the way of chemical information and principles that they can carry with them and use, to make the universe a more familiar place to them. The problem is to get a suitable balance of theory and practice while doing this.

Let's look at some topics of this sort and see how they relate to chemical theories, which can be presented simultaneously:

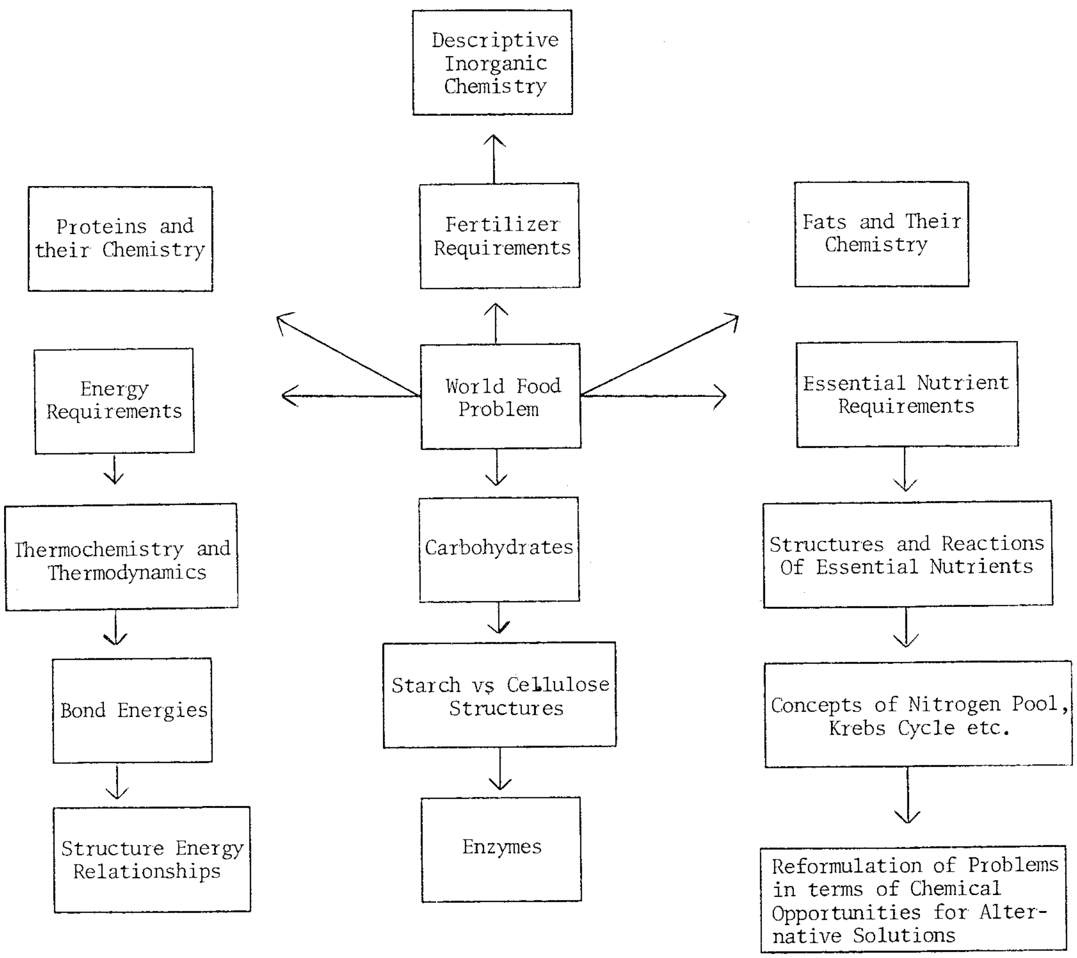
FOODS →	Thermodynamics via Calorie Requirements
	Osmotic Pressure via Preservation with Salt or Sugar
	Vitamin Biochemistry
	Free Radical Chemistry via Food Antioxidants
	Chelating Agents via Preservation
	Gas Chromatography via Flavors
	Color Theory via Food Colors
	Colloid Chemistry via Most Topics in this area
MEDICINES →	Biochemical Reactions
Antacid Tablets →	Acid-Base Chemistry
Birth Control Pills →	Steroid Chemistry
Drug Activity →	Optical Isomers
	Stereochemistry
BEAUTY AIDS →	Colloid Chemistry esp Emulsions
	Principles of Solubility
	Protein Structure and Reactions
	Dye Chemistry
	Spectrophotometry (eg SunTan Lotions)
	Organic Reactions · (Perfume Constituents)
	Polymers
STAIN REMOVERS →	Redox Chemistry
AUTOMOTIVE PRODUCTS →	Colloid Chemistry
	Colligative Properties
	Organic Reactions
PHOTOGRAPHY →	Chemistry of the Solid State, Defect Structures
	Redox Reactions
	Color Theory
PAINTS →	Polymers
	Colloids
	Color Theory
	Free Radicals
FUELS →	Thermochemistry and Thermodynamics

Generating New Topics in This Area

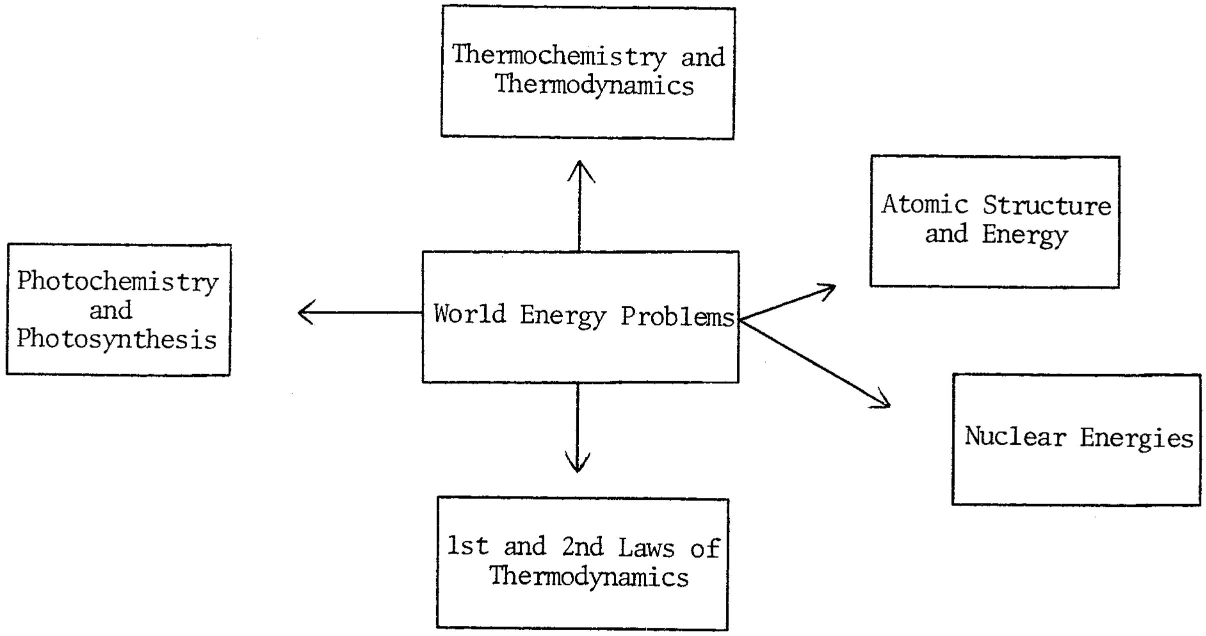
There are at least four routes to new topics of this sort which can enhance student interest:

1. Topics suggested by students.
2. Items in the news.
3. Recognized regional problems.
4. Advertisements of new products, etc.

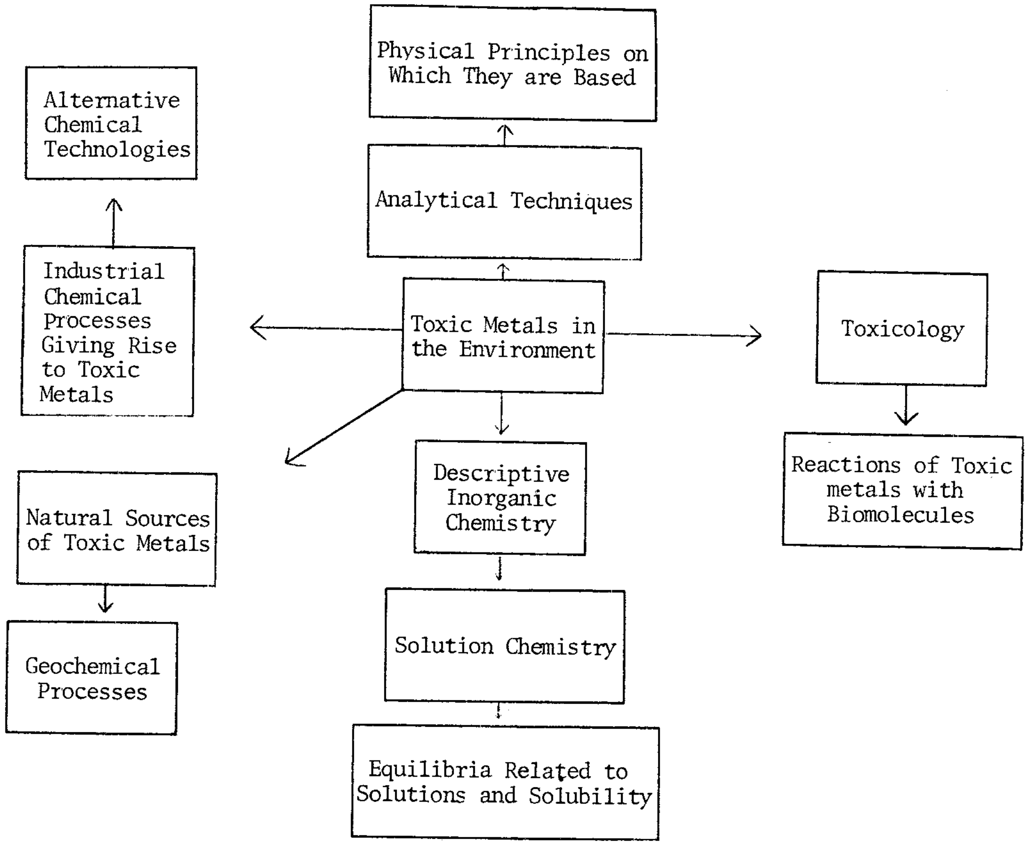
The diagrams show how three of the current newsworthy problems of our world can be used as a starting point. From these we can develop an analysis that goes from the problem to the scientific theories that can serve as guides and criteria for their proposed solutions. There are probably many more students who can reach some understanding of the laws of thermodynamics (by way of the limitations they put on specific solutions to the energy problem) than can appreciate a purely theoretical approach to these laws.



Development of Some of the Basic Chemical Topics Related to the World Food Problems



Development of Some of the Basic Chemical
Topics Related to the World Energy Problem



Topics Which Can Be Developed From
A Study of Toxic Metals In The Environment

Formulating a laboratory for such students is a real problem. As far as possible, the experiments should be relevant, without overtaxing the limited laboratory skills of the students. My colleagues and I have been working on this laboratory problem for about 5 years. We have developed an approach which combines an initial group of experiments that develops basic laboratory skills. This is followed by a further group of experiments in which the students:

1. Make an aluminum compound from an aluminum can (give history, etc.).
2. Make alcohol by fermentation and concentrate it via distillation.
3. Synthesize some simple organic compounds, several of which have found use as drugs (aspirin).
4. Make soap, dye fibers, make polymers, study enzyme reactions, run blood glucose, isolate proteins, titrate hard water, run Chemical Oxygen Demand, make a face cream, analyze a face powder, and determine low levels of mercury, etc.

Such experiments must be kept as simple as possible technically, so that the point they illustrate is not lost in a confusing welter of experimental complexities.

CONCLUSION

The final justification of such an approach can only be given in terms of its success in stimulating and maintaining student interest in the study of chemistry. At the present time we must admit that many students are unwilling to invest the time and effort required by the study of chemistry unless we show them how it will enlarge their understanding of their immediate environment. For this reason, I believe that elementary chemistry courses need consumer chemistry topics. They can be an important part of a course which is intellectually respectable and they can furnish the connecting threads that tie a student's understanding of elementary chemical theory to his immediate experiences.

CHEMICAL TECHNOLOGY

The Techologist: Objectives and Status Within the Chemical Institute of Canada

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Presented to a General Session of the Forty-Fifth Two Year College Chemistry Conference, George Brown College of Applied Arts and Technology, Toronto, Ontario, May 29, 1975.

The Committee on Certification of Chemical and Biochemical Technicians and Technologists has been active within the Chemical Institute of Canada since 1961. The original Certification Board set up by the C.I.C. had two functions; (1) to determine which courses should be recognized (or accredited) and, (2) to certify individuals who had either graduated from a recognized program, or had written examinations after outside study.

As more and more Technicians and Technologists were entering the workforce three categories were used for certification: Chemical Technician, Senior Chemical Technician, and Chemical Technologist. These categories still stand today.

After an applicant had been certified, he or she could not automatically become a member of the C.I.C. Prior to 1971, he or she could only apply for affiliate membership. It was argued within the C.I.C. that this practice discriminated against Technologists; as in many cases, graduate Chemical Technologists had more formal training in Chemistry, Physics and Mathematics than certain university graduates with "pass" degrees in chemistry.

The accreditation of programs is now based on a minimum of 1600 hours of instruction in chemical subjects and minimal outlines are described in the C.I.C. publication "Requirements for Certification and Outlines of Curricula".

Before I go any further, I think I should digress for a moment to define the term "Technologist". Those of you from the United States may not be familiar with the Canadian connotation of this term, as we seem to be a distinct species on the North American Continent.

A technologist is not a technician, a chemist nor an engineer. A Technologist's training and education emphasizes the application of principles rather than their development. That is to say, through an understanding of chemical and physical principles the technologist is an "Application Specialist" whose main contribution is an understanding of, and functioning within the interface of available technology and chemical systems. This is a very different approach when compared to the classical university education in chemistry.

In June of 1973, after a two year study and a major Task Force Report, the C.I.C. saw the birth of a new constituent society--The Canadian Society for Chemical and Biochemical Technology. That June meeting saw the first executive elected and a constitution approved.

The Executive and Board of Directors of the C.S.C.B.T. has set up a constructive dialogue within the C.I.C. about our status and needs. Over the past two years we have fostered a growing membership of both Technologists and Technicians, but the main thrust over this period has been the full recognition of the Technologist as a Technologist by the C.I.C. This has been accomplished to some degree.

Just exactly what is the C.S.C.B.T.? The C.S.C.B.T. is a full constituent society of the Chemical Institute of Canada. It has its own constitution within the C.I.C. Charter as defined under the British North America Act and it has definite aims and objectives.

The objectives of the Society are the advancement of the performance of chemical and biochemical technology, the maintenance and improvement of standards of practitioners of such technology, and the continuing elevation of chemical and biochemical service in Canada. More specifically:

1. To develop and maintain high standards in the profession and enhance the usefulness of chemical and biochemical technology to the public; to provide for the delivery and holding of lectures, exhibitions, p public meetings, classes, examinations and conferences calculated directly or indirectly to benefit or advance the work, aims, and objectives of the Society.

2. To administer and promote the well-being and interests of chemical and bio-chemical technologists by such means as a Members' Register and by the operation of local sections for the acquirement and interchange of technological experience and knowledge.

3. To inform perspective employers of chemical and biochemical technologists about the Society, its aims and objectives, and to familiarize them with the standards of the technologists.

4. To establish scholarships, prizes, and medals for worthy persons involved in practicing, studying or promoting chemical or bio-chemical technology.

5. To form local sections and student chapters for the advancement of these aims and objectives.

The C.S.C.B.T. is now looking at ways we as Technologists can better and help ourselves. We are considering a technical "Fellowship" or"Liscentiate" which would be the highest degree of professional technical recognition the C.S.C.B.T. could bestow on a Technologist.

We are involved to a very large degree in trying to form local sections, to present programs of advanced "technical" training and to educate the people around us as to what a Technologist is.

The Federal Government has anticipated this move to a degree in that in 1970-71 they decided to hire technologists on a competitive basis with B.Sc. graduates. The only problem is, they still will not allow the Technologist into "middle management" positions. This is the type of "work" the C.S.C.B.T. has to do right now. It is to convince the employer in the workforce that the technologist is trained and educated to a high degree and should not be held back from "middle management" positions simply because a university degree is lacking.

There are other ways the Technologist is discriminated against, and we are locating these problems and dealing with them one way or another.

In short, the C.S.C.B.T. is a Society for Technology. Its main function is and will be to respond to the wants and needs of Technologists across Canada.

We are trying to achieve an interaction of technologists with technologists and with areas of other professions; but, the role of the technologist within the C.I.C. is still not completely defined after two years of active debate and dialogue. The Canadian Society for Chemical and Biochemical Technology (C.S.C.B.T.) has, up to this point, been placed in the position many individual Technologists find themselves. This is a "grey" area of overlap with uncertain status, usually leading to a dead-end position and not a career.

The fact that the C.S.C.B.T. has existed since 1972 has clarified matters to some degree and a further move by the C.I.C. has more forcibly brought home the question of Technologists' status to the Chemical Community in Canada.

In February of this year, the C.I.C. Winter Council meeting, after studying a report from the Director of Professional Affairs, passed a motion that courses accredited by the C.I.C. Committee on Certification of Chemical (and Biochemical) Technicians and Technologists are approved under Bylaw 6(b). This was ratified at the May meeting here in Toronto. To quote Dr. H.W. habgood, Chairman of the Board of the C.I.C. in his February newsletter; "Council has finally opened the door to major admission of technologists as full members - a process set in motion some years ago. By so doing, we in effect, are challenging the C.S.C.B.T. to get its new constituent society into high gear. And the Executive of the C.S.C.B.T. is ready to rise to the challenge. The Technologist may well become a major part of the chemical community within the next decade or two".

Before I describe what I feel is "high gear" within the C.S.C.B.T., I would like to elucidate the various links which exist between the C.S.C.B.T. and the Committee on Certification of Chemical (and Biochemical) Technicians and Technologists.

The Committee on Certification is now composed of industrialists, educators from the technological sector, and technologists. It now reports to both the Professional Affairs Branch of the C.I.C. and the C.I.C. Committee on Academic Qualifications. We, as Technologists, now have a major input into this committee, while this committee determines the educational standards of the C.S.C.B.T. membership. I should mention that a Biochemical syllabus has been added to the "Requirements for Certification and Outlines of Curricula".

This means that a forum of Industrialists, Educators and Technologists assess the acceptability of candidates for certification and accredited programs in various schools and institutes of technology across Canada. I do not find this a bad thing at the present time. Technologists as a group still need to mature and grow. We stand today, a brash young group composing about 8% of the total membership of the C.I.C. Very few Technologists are past the ripe old age of 35.

I sometimes allude to the Technologist being teenagers in their grandparents house. The Technologist does not have a total maturity that long experience gives, and is still willing to try anything, at least once.

On the other hand, I think older members of the C.I.C. are suffering from "Future Shock". The type of recognition the Technologist demands does not quite fit the chemist's idea of a professional evolving from Ivy Covered Buildings.

The Technologist is a new and aggressive breed. I think we may evolve in a manner that no one person or group foresaw when this experiment in education was begun in the early 1950's.

But, back to the "high gear" of the C.S.C.B.T., the C.S.C.B.T. with the cooperation of the Committee on Certification will in future attempt to define national employment trends and manpower needs. A membership register will be produced and more local sections will be established.

The C.I.C. has developed a new policy for Student Members. This scheme, which will go into effect this September, stipulates that all students registered in C.I.C. accredited courses will be registered as Student Members and no fees will be charged. The half-year after graduation will also be "gratis", while the full year following graduation will see a charge of one-half the current fee levied against the individual if that person is still a C.I.C. member. If this system takes root, we should be able to maintain contact with graduate Technologists wherever they move.

It is hoped that local C.S.C.B.T. sections will be useful for those technology programs in the confines of the local section. The alumni of the Schools/Institutes of Technology are not used enough in assessing the effectiveness of the programs. Although some technologists have gone back into the educational field, I have still to observe many programs which utilize graduate technologists in any form of an advisory capacity; either in Advisory Committees for programs, or in follow-up assessment of the program.

The C.S.C.B.T. will be promoting the dissemination of technical information and further education of a related nature.

We have established a competition based on Technical Reports. I believe most of you are already aware of this competition, which we hope will become an annual event.

The Manitoba section of the C.S.C.B.T., in conjunction with Red River Community College, is setting up advanced (post-graduate) courses for Technologists, in areas where advanced training is felt to be of benefit.

In the future we will be presenting technical symposia and workshops to augment and upgrade technical skills and knowledge.

Committees are being set up to study Science Policy now being proposed in Canada. I believe we as Technologists and you as educators of Technologists, must keep a close watch as Science Policies develop, and we must have an input into these matters. Science Policy could, and possibly will, determine to a degree the type of employment Technologists will find in the future.

In summation, effort has been expended on behalf of the C.S.C.B.T. to establish some sort of recognition of the Diploma of Technology and the certified Technologist. The way is now open for Technologists to be recognized professionally by the Chemical Institute of Canada. This means that Technologists can now become full "professional" members of the C.I.C. under Bylaw 6(b).

We must now be prepared to take the issue of our education and qualification, through debate and dialogue, to the workforce itself. The Technologist must make an individual and collective effort to inform those people and employers we have contact with, that we do have an education and definite capabilities.

There are at present about two thousand graduate Chemical and Biochemical Technologists from C.I.C. accredited courses across Canada. The Canadian Society for Chemical and Biochemical Technology (C.S.C.B.T.) can only do a certain amount of work to ensure recognition of the Diploma of Technology and the Certified Technologist. The Technologist as an individual, in the final analysis, must prove what he or she is capable of within his or her chosen discipline.

Science and Engineering Technology

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Presented to a Special Session of the Forty-Seventh Two Year College Chemistry Conference, Shelby State Community College, Memphis, Tennessee, November 1, 1975.

The Science and Engineering Technology Curriculum is a two-year associate degree curriculum involving a significant measure of applied chemistry, applied physics and applied electronics. The objectives of the SET curriculum are the following:

1. To prepare technicians to work in the growing number of jobs lying in the interface regions between the traditional specialties of engineering and science.
2. To appeal to a body of potential students presently untapped by curricula in the traditional specialties of engineering technology.
3. To provide job placement potential at the associate degree level.
4. To offer a superior amount of transferability for those graduates deciding to continue their education to the baccalaureate level on a full-time or part-time basis at a later date.
5. To develop a technical background less susceptible to obsolescence in a changing technical society and more amenable to continuing education in mid-career.

Practitioners in most fields of science and technology will admit to an identity crisis. In our academic institutions we can attempt to keep things nicely compartmented, but few of us would insist that knowledge or work in science and technology come in discrete packages which can be distributed like jelly beans into separate jars. New developments and activities transcent the traditional disciplines.

There will always be a need for a mechanical engineering technician, for example, who can do design work on a drawing board. But we have always known that many such people trained with an emphasis in mechanical design actually wind up working in an interface capacity with design. Some of us feel that, in fact more jobs are opening up in such interface regions than squarely in the center of the mechanical design field. In technical fields generally, only a very small percentage of us actually do what we were trained to do, even when we remain in that technical field. There has long been a need for interdisciplinary study. But, for one reason or another, we haven't been able to "bring it off" over a long enough period to insure stability.

Once I was told that the key to success is to wait for the right opportunity to come along and then jump. "How does one recognize the right opportunity?" "You keep jumping". In a sense the Science and Engineering Technology represents just one more jump. There are some indications that this could be the right opportunity.

We are witnessing a revolution in technology which will effect every field and every industry in remarkable ways. It has been caused by the low cost <u>integrated circuit</u>. How many of your students are using slide rules today? (Just two years ago, I found it necessary to teach the slide rule.) But pocket calculators are only one place where integrated circuits have made an impact. A more fundamental revolution is in an area which could be called "transducer Technology".

Ten years ago if one wanted to convert force, temperature, pressure or any physical parameter into an electronic signal he would need several things. First, a transducer costing maybe \$300.00 to \$600.00 would be required. Then an electronic black box generally called a signal processor would be needed to supply an excitation signal and/or to receive, modify and amplify the transducer signal into a usable form. The signal processing unit would cost perhaps \$1000.00. It would feed the processed signal to a "readout" of some sort, perhaps a digital voltmeter costing another \$1000.00.

Today the transducers cost about the same, but due to mass produced integrated circuits, the signal processor can be obtained for \$125.00 and the digital voltmeter for another \$150.00. The same dramatic reduction in cost, weight, and volume; and the increases in capability, and ruggedness that have occurred in electronic calculators have also appeared in transducer technology. The necessary items are "on the shelf" waiting to be applied to almost every laboratory or industrial activity.

Why does one want to convert a physical parameter into an electrical signal in the first place? We all know the reasons. You can amplify the devil out of it for any sensitivity you want. You can display it on a scope, recorder or plotter. You can store it magnetically for future use. You can feed it into an analog computer, or do an analog to digital conversion and use it in a digital computer. Now there are micro computers cheap enough to be dedicated economically to many laboratory or industrial processes. These uses are not confined to any one field like chemical technology or mechanical technology. Transducer application is a desirable thing in any area of science or engineering. It is a skill in itself, its own specialty, truly transcending the boundaries of traditional specialities.

One of the weaknesses of interdisciplinary programs is that they often have no focus. Graduates of such curricula may have a fantastic awareness of the problems associated with such concerns as aerospace, the environment, transportation or the energy crisis. But awareness is one thing while the ability to do something specific about it is quite another. The development of a space system, the solution of a polution problem, the use of an alternate form of energy conversion often involves the traditional specialties. And after the "race" or the "crisis" is over who is better off, the person with an awareness of yesterday's crisis or the one with skills which can be applied to a new problem? An interdisciplinary education must offer some specific skills. It should admit that there are some specific things that the product of the curriculum cannot do but at least one specific thing that he or she is prepared to do better than any other. Science and Engineering Technologists are not to be trained at all for design or design support work. Others can do that better. On the other hand, the evolved form of the SET Curriculum should be a superior base for the application of transducers and electronic instrumentation in a variety of fields.

The Science and Engineering Technician Curriculum has a substantial base of physics and chemistry. The approach to these two subjects is applied. Ideally the curriculum will use the most recently developed instructional materials in technical physics and chamical technology. In most other 2-year technician curricula, either physics or chemistry is traded off for the technical specialties. In Science and Engineering Technology physics and chemistry are part of the technician's specialty. The attempt is to give the broadest possible exposure to physical parameters and the relationships between them.

The Science and Engineering Technology Curriculum includes a sequence of courses with instructional objectives in the areas of transducers, electronic devices and components, analog and digital devices and instrumentation and controls. Here again a non-traditional approach is used. Circuit analysis will be de-emphasized. The characteristics and uses of "black boxes" is brought to the forefront. Ideally, instructional materials and equipment in applied electronics developed by Technical Education Research Centers of Cambridge will be employed where practical. Both physicists and electronics engineers will be teaching the courses as well as developing instructional materials in this chain.

The Science and Engineering Technology Curriculum is intended to appeal to those students interested in science or engineering; not necessarily in cars, stereos, drafting, building things or making things as is the typical student in the traditional specialties. It is assumed that there are students who are simply interested in science or engineering, but for a variety of reasons seek to invest in an education which will make them reasonably employable after only two years of full time study. Some experience in the implementation of the SET program supports this assumption. At Metropolitan College in Denver, where the initial offering of SET has enrolled over 30 students, half the inquiries about the curriculum were from women. That is not typical of the population normally interested in engineering or engineering technology. At Florissant Valley Community College about 24 students are enrolled, primarily in response to a mailing to "undecided" students. The indications are that SET will not compete with the traditional specialties but will draw new people into the human resources pool and prepare them for new kinds of jobs.

On the matter of employability, 531 likely employers in the areas of the cooperating colleges were sent questionnaires. 106 completed questionnaires were returned. The respondents represented organizations employing an estimated 15,000 associate degree technicians. 69% of the respondents indicated that the Science and Engineering Technician Curriculum appears to satisfy present employment needs. 81% replied that the SET curriculum appears to satisfy future employment needs.

It is believed that the stronger science base of the SET Curriculum will make the difference in the objectives of transferability and resistance to obsolescence. Transferability is really a function of the receiving institution, the chosen curriculum, and the individual student's track record. So hard documentation regarding transferability will not be possible within the three year time span of the project. However, the project has received mostly green lights from universities approached on this subject. Local transfer arrangements in the area of the colleges doing trial implementation os the SET Curriculum will be worked out. Transferability is seen to be an important to post-secondary education in a field which interests them. Also, there has been a growing trend among universities to provide meaningful opportunities for associate degree technicians to continue toward the baccalaureate.

The Science and Engineering Technician Curriculum Project is funded by the National Science Foundation for three years. During these years it will continue to bring together people from many geographical areas, industries and disciplines in order to design the curriculum. Also during this period there will be trial implementations at several colleges in several geographical areas. Due to the compressed schedule, design and implementation are proceeding in parallel. Study guides are at this time only completed for the first semester courses. and these are scheduled for revision. There is consensus on detailed course outlines only through the first year of the curriculum. The second year is still in the form of a curriculum outline. Yet students were enrolled in programs at seven colleges this fall and four of these colleges are preparing proposals to permanently adopt the curriculum.

The Wyoming Chemical Technology Program

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Presented to a Session on "Chemical Technology" of the Forty-Seventh, Two Year College Chemistry Conference, Shelby State Community College, Memphis, Tennessee, November 1, 1975.

The University of Wyoming and the seven Wyoming community colleges are currently engaged in a coordinated project involving the development of associate degree programs in chemical technology at the community colleges, and a new B.S. degree program in chemistry and chemical technology at the University. The community college programs are designed to be responsive to local needs for chemical technicians, as well as training chemical technicians for a broader-based national market. In addition, the associate degree programs are designed to be fully transferable to the new B.S. degree program at the University of Wyoming which has been developed in collaboration with the community colleges. The associate degree programs have considerable individual variation, but all attempt to meet the mimimum ACS recommendations for two-year programs. Since the concept of transferability was a major feature, the B.S. program at U.W. was also designed to correspond as much as possible to these general recommendations in the first two years. In regard there is more chemistry, particularly laboratory, in the first two years of the U.W. program than most traditional B.S. programs in chemistry. Most humanities, fine arts, and social sciences are taken in the upper two years. The courses in the new B.S. program are solidly based on chemical principles and probably contain more "theory" than some two-year programs. At the same time, we have shifted some of the educational emphasis in the traditional B.S. degree in chemistry from the theoretical aspects to the applied aspects since our new B.S. program is directed toward preparing a student to enter an industrial chemical environment (or other areas of applied chemistry) immediately upon graduation rather than preparing primarily for admission to graduate school. There are presently three other four-year schools collaborating with us on the development of such B.S. degrees in applied chemistry or chemical technology. These are South Dakota State University, The University of Lowell, and the Universities of Maine at Portland-Gorham and at Farmington. Other two-year schools associated with the project are

Northeastern (Colorado) Junior College, Aims College (Greeley, Colorado) and Mesa College (Grand Junction, Colorado).

Our aim is eventually to form some sort of an association of schools with programs in chemical technology and applied chemistry, so that students in a two-year program would know that they could know that they could transfer to one of several four-year schools after obtaining an associate degree.

Although we realize that many associate degree programs in chemical technology have been designed to train persons for direct employment upon graduation, we feel that the potential to transfer to a B.S. program might be a desirable additional feature. Thus, a student would not feel that he had entered a "terminal" program, and that if he changed his educational objectives while obtaining an associate degree or desired to return for more education after a period of employment (say up to two or three years) there would be some guarantee this could be done with little or no loss of credits already earned.

The various two-year programs in chemical technology training various types of chemical technicians are more or less recognized. The B.S. in Chemical Technology is at present a new concept, and only a few schools have degrees of this type. Nevertheless, the need for a B.S. chemist, problem oriented and better trained in laboratory skills, who can directly enter an industrial or applied field has been expressed by many. We have ascertained this need ourselves with an industrial survey, discussions with various ACS personnel, and other academic and industrial sources. We feel that coordination with two-year programs is important to aid in our planning, to provide for a potential continuing education for chemical technicians, and perhaps to benefit both types of programs by mutual collaboration.

As part of the collaborative effort with the Wyoming community colleges, many new experiments are being developed for courses in general, analytical, and organic chemistry, and instrumental analysis. These are being used both at the University of Wyoming and at the community colleges. As much as possible, these experiments make use of standard methods of analysis and "real" samples. Many are being developed with the help of consultants from the chemical industry.

We would be happy to make these experiments available to interested persons, and would appreciate comments on the concept of transferable two-year chemical technology programs integrated with four-year B.S. programs in chemical technology.

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COMMITTEE ON CHEMISTRY IN THE TWO-YEAR COLLEGE

Division of Chemical Education
American Chemical Society

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