DOCUMENT RESUME

ED 116 609 | IR 002 475

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TITLE	Computer Based Techniques Applied to Undergraduate Chemistry.
INSTITUTION	Texas Univ., Austin. Project C-BE.
SPONS AGENCY	National Science Foundation, Washington, D.C.
REPORT NO	EP-14-6-28-73
PUB DATE	28 Jun 73
NOTE	20p.; For related documents see IR 002 463 and 464
EDRS PRICE	MF-$0.76 HC-$1.58 Plus Postage
DESCRIPTORS	*Chemistry Instruction; *Computer Assisted Instruction; *Computer Programs; *Course Descriptions; Curriculum Development; Higher Education; *Individualized Instruction; Instructional Design; Instructional Systems; On Line Systems; Programed Tutoring; Program Evaluation
IDENTIFIERS	*Project C BE; University of Texas Austin

ABSTRACT

Realizing that each student has his own optimal learning environment and that the computer is a valuable tool in individualizing instruction, instructors at the University of Texas at Austin designed a chemistry course using the latest computer technology to assist the instructor and to maximize student achievement. The course consisted of lectures, textbook activities, and exams; for those students that showed weaknesses on the exams, remedial computer modules were available. The course was offered twice and results showed a positive effect on both student achievement and student attitudes. A list of computer modules, sample student-computer interactions, grade distribution data, and cost information are included. (EMH)

Project C-BE

GRANT GY-9340

COMPUTER-BASED SCIENCE
AND
ENGINEERING EDUCATION

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COMPUTER BASED TECHNIQUES APPLIED TO UNDERGRADUATE CHEMISTRY *

EP-14/6/28/73

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* This study was supported in part by Project C-BE under Grant GY-9340, "The Use of Computer-Based Teaching Techniques in Undergraduate Science and Engineering Education" from the National Science Foundation to the University of Texas, Drs. John J. Allan and J. J. Lagowski, Co-Directors.

COMPUTER BASED TECHNIQUES APPLIED TO UNDERGRADUATE CHEMISTRY*

S. J. Castleberry and J. J. Lagowski

Many of the procedures and techniques employed by instructors at large universities are controlled and necessitated by logistical considerations: large numbers of students, low numbers of instructors, classroom space, and record keeping. There have recently been numerous attempts to return control of the educational process to the instructor and student: the Keller Method[1] (PSI) audio-tutorial tapes, CAI (computer assisted instruction), CGRE (computer generated, repeatable exams), CMI (computer managed instruction) and CAL[2] (computer augmented lecture), to mention just a few.

We have attempted to combine some of these techniques and apply them to a general chemistry course. This paper will present these techniques, the results we have obtained, and the changes and adaptions which we think will be useful.

The techniques we have employed are a combination of CMI, CAI, PSI, contingency management[3], and self-paced, individualized instruction. In combining these techniques and designing the course, we have made the following assumptions: (1) the optimum conditions for learning are unique for each student; each student can learn more effectively when the

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*This paper was presented at the International Congress, "The Use of Electronic Computers in Chemical Engineering," sponsored by the Societe de Chimie Industrielle in Paris, France, April 25-27, 1973.

sequence of instructional material, the pace and mode of presentation and the style of instruction are tailored to his individual needs and capabilities. (2) An integrated system of human, hardware and software components presents the only viable method to offer large numbers of students highly individualized instruction. Planning[4] the utilization process for human components of a system must be completely integrated with the planning of machine and software utilization. The hardware/software functions are to present instructional material, collect data, analyze data, reduce data, and provide reports. The human functions include designing teaching strategies, interpreting data, counseling students, bridging the gap between existing software and current research, and obtaining behavioral objectives in the affective domain (i.e., influencing attitudes, motivating and inspiring students). All too frequently teachers become overly involved in attempting to help students learn in a poor environment, rather than teaching; that is, they have the burden of assigning, grading and giving feedback on homework and tests, helping students with their assignments, and conducting tutorial/ remedial drill group interactions. To a large extent the computer can perform these tasks (on an individual basis) as well as, or better, than the instructor. To allow large numbers of students to proceed through a self-paced course, taking different tests and modules at different times requires an automated record keeping system. To meet this requirement we implemented a CMI, contingency management system, which could automatically record computer administered test results, automatically record CAI module results, accept non-computer generated results, and provide student progress reports in the form of individual profiles on demand. This allowed both the instructor and the student to know exactly the student's status at any given time.

In order to understand the implementation of the system, it is necessary to know the structure of the course as taught by Dr. Lagowski. Figure 1 is the first handout the student receives; it shows the text and chapters used, the work distribution, and the grading schedule. The course consisted of one hour of lecture per week, one hour of small group discussion and one hour of computer interaction per week (the actual computer time varied with the needs and desires of the students). The three major examinations and ten quizzes were instructor generated, administered and graded. However, for each question on each test there was a corresponding test module on the computer which the students could use to make up low scores received on the paper pencil test. The computer test modules used random parameter generation techniques to insure that no two students received exactly the same question and that no student received exactly the same question on repeated trials. The computer administers the test, scores it (immediately giving the student his results) and then records the results in the student's data file.

Figure 2 shows the computer modules (tutorial/drill and simulation) available to the students and their point value. The modules are also keyed to the appropriate chapter in the student's text. The effectiveness of CAI as a teaching tool has been amply demonstrated.[5,6,7,8] Likewise, the rationale behind its development and application in general, and particularly in chemistry, has been well documented.[6,9,10,11] We shall, therefore, only briefly outline the philosophical points underlying our modules: (1) the modules supplement the instructor, not replace him; (2) the modules are designed to help students learn by doing, not necessarily to teach or merely transfer standard information; (3) the computer interactions are modular and independent, facilitating the individualization of student experiences in pace, sequence and content.

A few sample interactions will illustrate these points. Figure 3 is a sample student interaction on the module CHEM1, the gas laws. First, the module randomly selects the type of problem; whether the student will solve for pressure or volume or temperature using the combined gas law. Then the module randomly generates the numerical value of the parameters to be given to the student. In the student's first answer he does not convert to absolute temperature, and the module is able to diagnose this error and give the appropriate response contingent feedback. On the student's second answer, he is correct and is given an appropriate positive response. Figure 4 illustrates what happens when the student inputs a series of answers which are incorrect, and the module cannot diagnose a specific type of error. On the first response the student is given a broad clue; on the second response the student receives a more specific hint, and on the third response he is given the solution.

The above interactions illustrate a typical tutorial/drill type module; the following figures illustrate a typical simulation type module. Figure 5 is the initial interaction in CHEM32, a kinetics experiment in which the student's task is to collect sufficient data to determine (1) the order of reaction, and (2) the reaction rate constant. This module is really a series of decisions the student must make on the basis of his experience and the data he collects. He must decide the experimental conditions: concentration and the wave length at which to follow the reaction. Figure 6 shows the data upon which he makes the latter decision. He must decide if his data is satisfactory and how he is to treat the data. These decisions are shown in Figure 7. After the student has analyzed the data (on or off line), he takes a special module which checks and records his results.

The course utilizing our C-BE methods has been offered twice as a regular section of General Chemistry 302. We evaluated the course by: (1) comparing it to other non-C-BE sections in terms of student achievement; (2) determining costs per student hour; and (3) obtaining student attitudes. We controlled the comparison of sections for differences in entering skills and aptitude by using chemistry placement test scores and SAT-M and SAT-V test scores as covariables. Figure 8 shows the comparison data in terms of grade distributions. In these terms, the classes using C-BE techniques achieved a greater proportion of A's and B's. Figure 9 shows our cost data. It is interesting to note that these costs are based upon experimental charges, not the lower, regular departmental charges. Even at this rate, it is possible to reduce costs by optimizing and improving the system as the drop from $4.05/student hour to $2.07/student hour indicates. We can easily foresee the costs dropping to less than $1.00/student hour when the current department rates are used rather than experimental rates.

At the end of the course an attitude scale consisting of 51 items was administered to the students. The maximum possible positive score was 193. The neutral score was 96.5. The mean score of the 79 responding students was 156.6, which clearly indicates a positive attitude of the student towards C-BE techniques. Figure 10 summarizes the attitude scale data. The alpha coefficient shown is the coefficient of internal consistency and reflects the degree of reliability among the items of a scale in terms of overlapping variance.

Our results indicate that C-BE techniques can efficiently augment the teacher's efforts, and have a positive effect on both student achievement and student attitudes. In light of our results it is not difficult to foresee our general chemistry course becoming not one course but a different individualized course for each student. The content of the course (and hours of credit) to be determined on the basis of a placement test (on minimum core skills) and student desires (for optional units). The sequence and rate of progress of the student will be determined jointly by the teacher and student so that the course becomes self-paced within the limits agreed upon by student and teacher. The "course" is no longer constrained by the traditional time limits: semesters or quarters and credit hours. In this course, the teacher retains his usual teaching role, but trades the roles of bookkeeper, grader and all around paper shuffler for the roles of counselor and mediator.

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CHEMISTRY 302.12265 - FALL 1972
J. J. Lagowski
TTh 3-4:30
CHE 15

Text: Slabaugh and Parsons, GENERAL CHEMISTRY, Second Edition
Chapters: 7, 8, 9, 10, 11, 12, 13, 14, 15

Work Distribution:

1 Hour lecture every Thursday
1 Discussion period every Tuesday (schedule to be announced).
1 Session/week with computer (to be scheduled at your convenience).

Examinations: 3 October, 8 November, Final Exam Period 21 December, 9-12 am. Exams are scheduled for the evening of these days, 7:30-9:30 pm. In case of a conflict, please see me at least one week before the exam and individual arrangements will be made.

Quizzes: End of each lecture on Thursdays.

Grading Schedule:

	Points	Total
3 Major examinations	100 each	300
10 10-minute quizzes	10 each	100
12 Attendance at discussion periods	3 each	36
12 Attendance at lectures	3 each	36
14 Tutorial Modules	See list	150
7 Simulated Experiments	See list	160

A = 100 - 90%
B = 89 - 90%
C = 79 - 70%
D = 69 - 60%
F = 59% and below

Figure 1

CHEMISTRY 302.12265 - FALL 1972
J. J. Lagowski

TUTORIAL MODULES

CHAPTER	CODE	DESCRIPTION	POINTS
7	CHEM 1	The Gas Laws	15
9	CHEM 114	Henry's and Raoult's Law	10
9	CHEM 60	Heat of Vaporization	10
9	CHEM 61	Kinetic Molecular Theory Applications	10
10	CHEM 116	Colligative Properties	10
10	CHEM 113	Solution Concentration	10
10	CHEM 2	Solution Stoichiometry	10
11	CHEM 119	Equilibrium	15
13 (thru 13.5)	CHEM 107	pH, H^+ , pOH OH^-	10
13 (thru 13.9)	CHEM 124	Common Ion Effect	10
13 (thru 13.9)	CHEM 126	K_{sp}	10
14	CHEM 36	Redox Equations	10
15	CHEM 109	Elementary Thermochemistry	10
15	CHEM 139	Thermochemistry	15

SIMULATED EXPERIMENTS

CHAPTER	CODE	DESCRIPTION	POINTS
7	CHEM 3	Molar Volume of N_2	25
10	CHEM 115	Colligative Properties	20
11	CHEM 32	Reaction Kinetics	25
13 (thru 13.5)	CHEM 122	pH and K_i Determination	25
13 (thru 13.9)	CHEM 19	Titration	20
14	CHEM 127	Faraday's Law	20
15	CHEM 41	Calorimetry	25

REVIEW MODULES*

CHEM 20	Interpreting Formulas
CHEM 26	Balancing Reactions
CHEM 27	% Composition
CHEM 29	Interpreting Formulas
CHEM 30	Formula Writing
CHEM 36	Balancing Reactions
CHEM 105	Formula Writing
CHEM 43	Formula Weight
CHEM 44	Mole Ratio
CHEM 45	Mole Concept
CHEM 46	Wt/Wt Relations
CHEM 47	MW of Gases
CHEM 48	Volume-Volume Relations
CHEM 49	Wt-Volume Relations
CHEM 42	Mole Concept

* These modules can be used for review in the subject indicated if you think you need it. No credit is given for working with these modules since they contain information which you should be familiar with.

Figure 2

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THIS IS A SIMPLE PRACTICE SET ON THE IDEAL GAS LAW
WHEN YOU HAVE HAD ALL THE PRACTICE YOU WANT, TYPE "STOP'.


CALCULATE THE PRESSURE OF A GAS GIVEN THAT ITS MOLE WT IS
51.5 AND THAT 52 G OF THE GAS OCCUPIES 28231.2 ML AT
68.6 DEG C.
? CALC
WHEN YOU HAVE COMPLETED YOUR CALCULATIONS, TYPE
RUN 1090

STOP AT 1080

*OK
PRINT (52/51.5) * .082 * 68.6/28.23  .201198

RUN 1090
NOW YOUR ANSWER
? .201198
SORRY, NO.
YOU FORGOT TO CONVERT TO ABSOLUTE TEMPERATURE
REWORK THE PROBLEM AND ANSWER AGAIN.
? CALC
WHEN YOU HAVE COMPLETED YOUR CALCULATIONS, TYPE
RUN 1090

STOP AT 1080

*OK
PRINT/
PRINT (52/51.5) * .082 * (273 + 68.6) / 28.23  1.00188

RUN/
RUN 1090
NOW YOUR ANSWER
? 1.00 ATM
I'LL ACCEPT THAT.
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Figure 3

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CALCULATE THE VOLUME OF 6 G OF A GAS GIVEN THAT ITS
PRESSURE IS 763.2 TORR, ITS MOLE WT IS 20 AND THE
TEMPERATURE IS 61.5 DEG C.
? 30
SORRY, NO.
PV = NRT, R = .082 L-ATM/DEG
PLEASE ANSWER AGAIN.
? 40
SORRY, NO.
V = NRT/P, N = WT/MOLE WT = .3
PLEASE ANSWER AGAIN.
? 60 L
YOU BLEW IT AGAIN
V = .3 * .082 * 334.5 * 760 / 3 = 8.1942 L
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Figure 4

YOU ARE BEGINNING AN EXPERIMENT SIMULATION IN WHICH
YOU WILL FOLLOW THE REACTION A→B

ENTER YOUR UNKNOWN NUMBER.
1234

THANK YOU.
IN THIS EXPERIMENT YOU WILL COLLECT
DATA WHICH WILL ENABLE YOU TO
DETERMINE THE ORDER OF REACTION AND CALCULATE THE
RATE CONSTANT AS EXPLAINED IN THE HANDOUT FOR THIS
EXPERIMENT.

IN ORDER TO OBTAIN THE APPROXIMATE DURATION YOU MAY
LOOK AT THE ABSORPTION SPECTRA AT SEVERAL DIFFERENT
TIMES.
WHAT CONCENTRATION (IN MOLES/LITER) OF A WILL YOU
USE FOR THE INITIAL CONCENTRATION?
.5
AT WHAT TIME (IN SECONDS) DO YOU WISH TO SEE THE SPECTRA?
10

Figure 5

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HIT THE RETURN TO CONTINUE
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Figure 6

YOU MAY NOW OBTAIN EXACT ABSORBENCY DATA OVER YOUR DESIRED RANGE OF TIME AND AT TIME INTERVALS SPECIFIED BY YOU.

AT WHAT WAVE LENGTH (IN CM-1) SHOULD WE FOLLOW THE REACTION?
3500
EXCELLENT CHOICE.
WHAT TIME (IN SECONDS) DO YOU WISH TO BEGIN THE OBSERVATIONS?
1
WHAT INCREMENT (IN SECONDS) DO YOU WISH?
10
AT WHAT TIME (IN SECONDS) DO YOU WISH TO END YOUR OBSERVATIONS?
171
WITH WHAT CONCENTRATION OF REACTANT TO YOU WISH TO START?
.9

TIME	ABSORBENCY (AT 3500 CM-1)
1.0	.7425
11.0	.5782
21.0	.4789
31.0	.4125
41.0	.3648
51.0	.3290
61.0	.3011
71.0	.2788
81.0	.2605
91.0	.2452
101.0	.2323
111.0	.2212
121.0	.2116
131.0	.2032
141.0	.1958
151.0	.1892
161.0	.1832

ARE YOU SATISFIED WITH YOUR DATA?
YES
GOOD.
WOULD YOU LIKE TO SEE A PLOT OF YOUR DATA?
YES
O.K.
WHAT KIND OF PLOT?
(X = MOLES REACTION, A = ORIGINAL CONCENTRATION OF A, T = TIME)

A. ((A-X) VS T
B. LN(A/(A-X)) VS T
C. X/(A(A-X)) VS T

Figure 7

COURSE GRADE DISTRIBUTIONS

	A	B	C	D	F
COMPUTER SUPPLEMENTED (1971)*	70%	9.7%	6.1%	1.2%	13%
COMPUTER SUPPLEMENTED (1972)*	44.3%	17.7%	4.2%	1.4%	21.1%
TRADITIONAL CLASS*	10.4%	25.6%	18.4%	14.4%	31.2%
TRADITIONAL CLASS	18.7%	33%	26.4%	12.7%	9.2%

*Same Instructor

Figure 8

STUDENT USE COSTS

	# JOBS	TM HRS*	COMPUTER COSTS	LINE COSTS	STUDENT HRS.
Fall 1971	2291	18.944	$ 4925.48	1613.57	1613.57
Fall 1972	7440	24.63			

	COST/ STUDENT HR	RATIO STUDENT HR/TM HR	COST/ ACCESS	AVERAGE TIME/ ACCESS
Fall 1971	4.05	85/1	--	--
Fall 1972	2.07	147/1	$ 0.92	40.9 min

*TM HRS = CPU HOURS + PERIPHERAL OPERATIONS TIME FACTOR

COMPUTER COST FIGURES ON THE BASIS OF $256/TM HR

Figure 9

ATTITUDE SCALE

Number of items	=	51
Maximum possible score	=	193
Neutral score	=	96.5
Scale mean for 79 responding students	=	156.6
Alpha	=	.55

Figure 10