DOCUMENT RESUME

ED 084 770 EM 011 491

AUTHOR Stotter, Philip L.; Culp, George H.
TITLE The Use of Modular Computer-Based Lessons in a Modification of the Classical Introductory Course in Organic Chemistry.
INSTITUTION Texas Univ., Austin. Dept. of Chemistry.
PUB DATE Aug 73
NOTE 27p.; Paper presented at the American Chemical Society Symposium (Santa Cruz, California, August 19 through 24, 1973)

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS *Autoinstructional Programs; Chemistry; *Chemistry Instruction; College Students; *Computer Assisted Instruction; *Curriculum Design; *Curriculum Development; Higher Education; Individualized Instruction; Individualized Programs; Organic Chemistry; Program Descriptions; Self Pacing Machines; Simulation; Tutorial Programs; Tutoring; Undergraduate Study
IDENTIFIERS CDC 6400 6600 Computer System; CLIC; Computing; Conversational Language Instructing

ABSTRACT

An experimental course in organic chemistry utilized computer-assisted instructional (CAI) techniques. The CAI lessons provided tutorial drill and practice and simulated experiments and reactions. The Conversational Language for Instruction and Computing was used, along with a CDC 6400-6600 system; students scheduled and completed the lessons at their own individual paces. Since CAI accomplished the routine instruction, weekly lectures were reduced from three to two, but more time was devoted to essential theoretical concepts and student problems. Students did spend greater amounts of time on the lessons, but achievement was greater, especially for students in the lower and middle ability ranges. Students' attitudes were positive, and they developed self-reliance and independence which helped improve their lab performances. Experience with the course convinced its authors that students can take a more active part in organic chemistry instruction. In addition, it was concluded that both the traditional and the experimental approaches placed great time demands upon students and that further modularization was not necessary, but that increased attention should be given to the synthesizing of individual units into interdependent constructs. (Author/LB)

THE USE OF MODULAR COMPUTER-BASED LESSONS IN A MODIFICATION OF THE CLASSICAL INTRODUCTORY COURSE IN ORGANIC CHEMISTRY

Philip L. Stotter
George H. Culp

Department of Chemistry
University of Texas at Austin
Austin, Texas 78712

Abstract

The traditional design of instruction for an introductory organic chemistry course of one hundred chemistry and chemical engineering majors has been modified to include the use of computer-based, modular tutorial lessons as a required part of instruction. One hour per week of the traditional three-hour formal lecture presentation has been replaced by these computer-based lessons which provide a new dimension of self-pacing for the student participant in the following areas of tutorial instruction and drill: chemical nomenclature, simple reaction mechanisms and processes, synthetic transformations and sequences, interpretation of spectral data, interpretation of simulated experimental laboratory observations, and the methodology of reporting laboratory results and observations. Students are free to schedule interactions with the computer at their convenience and may repeat lessons as often as is necessary, but must show satisfactory completion of each lesson and its attendant drill questions. The collection of modular lessons frees the instructor to use the remaining class lecture time (two hours per week) for intense discussion of more difficult theoretical concepts, without the necessity for extensive in-class drill and numerous objective examples.

Course design and modification of pedagogical strategy, student achievement and attitudes, and more-general reflections deriving from our first full-scale use of these techniques in teaching organic chemistry will be discussed.

Introduction

The feasibility of using computer-based instructional techniques in undergraduate organic chemistry has been documented and described previously.[1-6] The earlier studies at the University of Texas at Austin using programs developed by Dr. G. H. Culp with the cooperation of Professors L. B. Rodewald, P. L. Stotter, and J. C. Gilbert, were conducted under experimental conditions in which randomly selected groups were given access to computer-based lessons and compared in terms of performance and attitudes with a control group from the same class. In each case the groups were relatively small in number and, with the exception of access to supplemental computer-based lessons, the course was conducted in the traditional method of three 50-minute lectures and one 4-hour laboratory per week. We present here a description of the first major experiment in which the conventional introductory organic course was extensively modified, based on these earlier studies, to include computer-based instructional techniques within the curriculum.

Course Design

At the University of Texas, Austin, introductory organic chemistry, Chemistry 818 (designed primarily for majors in chemistry, pharmacy, and chemical engineering), is taught as a two semester 8-credit-hour course. The course structure normally includes three 50-minute lectures (or two 75-minute lectures) and one four-hour laboratory, weekly. One section of the first semester of this course taught by P. L. Stotter in Fall, 1972, was designated as the experimental course. The text used was "Organic Chemistry" by Morrison and Boyd (2nd edition). Of the 106 students originally enrolled at the beginning of the semester, 73 students completed the course (the balance received grade designations of Q, $F_{abs.}$, and X, as shown in Table II).

The design of the experimental course differed from that of the traditional course described above in several respects. The number of formal lecture sessions was decreased from three to two 50-minute meetings per week. The originally scheduled meeting time reserved for the standard third formal lecture was used as an optional discussion period. Twenty-one computer-based lessons (average length ∿35 minutes each) (see Table I) were assigned as a required part of the course.[a] Students scheduled their computer interactions at times convenient to their own schedules and used standard teletype consoles. The lessons were written in CLIC (Conversational Language for Instruction and Computing), an interactive computer language developed by personnel of the University of Texas Computation Center and designed for the University of Texas CDC 6400-6600 system. A minimum level of achievement of 85 percent was established for most of the lessons. Until this level was attained, the student received no credit for the lesson interaction, but was allowed to repeat the interaction as many times as he wished without penalty until he demonstrated a satisfactory performance.

The regularly assigned laboratory periods were not modified.

A priori, this modified course design was predicated on the now-documented rationale for using computer-based instructional techniques, i.e., there are certain aspects within the learning process that may be treated more effectively by computer-based tutorial interactions, with the potential of providing self-paced, individualized instruction, than by classroom-structured human interactions. In this regard, the computer lessons emphasized areas that require drill--often patient, tutorial drill--as well as chemical logic and simulated experiment and reaction applications (in which the student may control several experimental parameters without the constraints of available time, equipment, and space). Furthermore, this design allowed the instructor to be freed from much of the routine instruction inherent within the traditional approach,

[a] A brief abstract including performance objectives for each lesson is available from the authors.

and the two weekly lectures were devoted almost entirely to more-generalized theoretical concepts of bonding, structure, stereochemistry, and reaction mechanism.

Three hour exams totaling 500 points and a final exam totaling 650 points were given. Points were also assigned to the semester laboratory grade (A=400 to D=100) and 150 points were credited to students who had successfully completed at least 20 of the computer lessons. Ten points were deducted for each lesson not completed. The course grade was contingent upon the total number of points attained.

Pedagogical Rationale

We have, for some time, believed that traditional organic chemistry instruction fails to utilize its available instructional resources very efficiently. In the past, our traditional classroom presentation has tended more towards training of undergraduate students, encouraging their passivity, than towards educating them. "Educating them" implies to the authors the necessity of allowing and encouraging student acceptance of an active, aggressive student role in defining his own learning experience. However, time makes such an approach difficult. Traditionally, as instructors of introductory organic chemistry, we have assigned comprehensive texts and then, too often, have found it necessary to spend most of our lecture time digesting and condensing the textual material. And we have, the authors believe, with disastrous results encouraged our students to expect such presentation, *i.e.*, we have encouraged them to believe that their role should be, and will be, a passive one and that any demand for more active student participation is unreasonable. The more comfortable and effortless we make his passive training experience, the better the organic student believes the quality of his instruction to be. Accordingly, a commonly heard student evaluation of chemistry lecturers is, "That instructor is really good; his lectures are so clear, logical, and comprehensive that I don't have to use the text at all".

A more efficient use of text and lecturer seemed to us to be one where each complements the other. For five years, one of us (PLS) has attempted to convince his own undergraduate students that their text must be their primary source of information, that lectures would supplement and clarify, and would attempt to demonstrate alternate logical constructs and relationships in addition to those well-defined by the text. He has further suggested that completion of assigned reading schedules, problems, etc., was an essential learning responsibility (whether or not all the content detail were discussed in lecture). Unfortunately, his students have not been willing to accept such responsibility. He found he could not depend on his students to work through material unless it was well discussed in lecture. And, further, he found they were unable (or unwilling) to use a detailed discussion of one topic as a model for logical thinking about related topics (unless specific demonstrations of how the model should be applied were included in lecture). Unfortunately, two semesters of lectures is insufficient for such detailed discussion of all the content of a comprehensive, thousand-plus page text.

Several alternatives seemed possible. Assign a simpler, less detailed text for "overview" and complement it with a lecture series of comprehensive detail. Or assign a comprehensive, detailed text (as is traditional) and complement it with selected, but deeply-developed, examples of generalized theoretical "overview", <u>and</u> with individualized tutorial drill to reinforce the text. Although it seems a more viable choice for comprehensive understanding of organic chemistry, the latter possibility, however, requires that students be convinced that their role is an active learning one, that lecture presentation will not fulfill the role of elementary training, and that the responsibility for correlating different, but related, information from various sources is their own.

In this regard, the division of lecture presentation into separate and disparate sections, one section to provide elementary drill and practice and one to demonstrate in-depth development of new logical relationships, seemed constructive. This fragmentation, we hoped, would necessitate active participation from each student in accepting responsibility for his own individual and highly personal <u>synthesis</u> of information from all disparate instructional sources. And, further, computer-based techniques might well be incorporated, not only to provide efficient, individualized tutorial drill, but to accentuate this division of lecture material; to the student involved in this learning experience, the computer and lecturer would obviously be disparate information sources in terms of content, style, purpose, and physical presence. We hoped that, when faced with the necessity of correlating information derived from these various cognitive information sources, a student who "put together" a coherent, meaningful entity from textbook, lectures, and computer lessons would have <u>learned</u> organic chemistry via a personally meaningful experience.

Accordingly, the experimental course was designed to include the following: assigned readings and study problems in the text covering chapters 1 through 12, 14 through 17, 25, 26, 28, 35, and parts of 13 and 21; the computer lessons indicated in Table I which were intended to reinforce specific areas of objective detail covered by the text; two 50-minute lectures per week which used structure, stereochemistry, and mechanism as their organizational focus, to provide contrast with the functional group organization of the text and computer lessons.

It was made clear that objective detail (such as simple reactions) was to be learned during the semester from the text source, aided by computer lessons; that some of this detail would be incorporated into the formal lectures, but that the instructor had no intention of reviewing all the detail of the text; and, finally, that such objective detail not covered in computer lessons was nonetheless each student's responsibility. During what would have been the third formal lecture hour of a traditionally constructed course, an optional and informal question-answer-discussion period was scheduled to handle problems and difficulties students might encounter in their "auto-instruction". Accordingly, the lecturer was often requested to give mini-lectures concerning specific detail or covering specific objective topics during this informal meeting.

Evaluation

In Table II is a comparison of student background abilities and performances (as indicated by SAT mathematics and verbal scores and by grade distribution) for the experimental class and a more traditional class taught by the same instructor 30 months earlier. It should be noted that the earlier class is not a directly appropriate control because of two characteristics: first, some of its students had access to a limited number of computer-based lessons; and, second, it was taught in the spring semester and, consequently, contained a large number of repeating students. For this reason, the grade distributions were also compared with two traditional courses taught by different instructors during the same (or closely related) time periods. In addition, anonymous attitudes and opinions were formally solicited from students in the experimental class.

Results and Discussion

<u>Student Performance</u> Students apparently accepted the fact that materials not discussed in computer lessons or lecture but assigned in the reading (<u>e.g.</u>, much of the objective detail concerning acetylene reactions) were nonetheless their responsibility, since their examination performances showed quite satisfactory grasp of such objective detail.

The distribution of course grades and other pertinent data for the four classes are shown in Table II. In terms of achievement, the data suggest an equivalence of background ability for the two classes with the same instructor, (X), and, most important, that the experimental approach is on a level equal to, or better than, the traditional approach. In this comparison, improvement is indicated in the middle and lower achievement groups for the experimental class, supporting the findings of the earlier studies in organic chemistry that show these groups can most benefit from the individualized, tutorial-drill instruction provided by the computer-based lessons. Comparison of the experimental class with the two traditional classes taught by different instructors indicates no significant differences in the distribution of passing grades. However, it is interesting to note the small percentage of failing grades and the relatively high percentage of drops without penalty for the experimental course. We believe these data suggest that in the experimental course each student was better able to determine--early in the semester--whether he would devote the time sufficient to complete the course successfully and, if not, drop without penalty while his work was still at a satisfactory level.

Perhaps the most viable statistical evidence for evaluating the learning effectiveness of students in the experimental course, an indication of their performance in subsequent organic chemistry courses, is not yet available. However, preliminary data, such as examination scores, indicate that students who transferred from the experimental course to a more traditional second semester course are performing satisfactorily (as judged by comparison of current exam grades with the final course grades they earned in the experimental course). One other phenomenon of interest is the performance of students from the experimental course who are now repeating the first semester with another instructor in a section using traditional presentation. (In the experimental section these students received grades of D, F, F_{abs}, and Q which are not satisfactory prerequisites for Chemistry 818b.) It is not yet possible to give an accurate description of their current progress; but, again, preliminary examination data suggest they may be performing at a success level higher than that normally expected of typical repeaters.

Three of the computer lessons were directly related to the laboratory portion of the course: one to gathering, interpreting, and reporting laboratory results; and two to simulated experiments prior to related, real experiments in the laboratory. Table III shows a general improvement in laboratory performance for the experimental class. However, the instructor finds it difficult to believe that three computer-based laboratory lessons were, alone, responsible for the unusually high laboratory performance; and this feeling is shared by the students involved. Perhaps a more appropriate explanation for the trend can be found in the greater degree of student self-reliance and independence necessitated by the overall experimental course structure. If these qualities carried over into his laboratory work, we might well expect such a student to come to laboratory better prepared and more likely to accept initiative and responsibility in conducting his own experiments. That the data is meaningful is best indicated by two facts: in laboratory sections, students of the experimental course were randomly mixed with students of a traditional course; and, at the University of Texas, introductory organic laboratory (instruction and grading) is normally carried out by personnel other than the formal lecturers of the course. Considering that the laboratory grade is based primarily upon experimental work, laboratory reports of real experiments performed, and performance on quizzes related to technique and/or theory, the grade distribution suggests that the experimental course design and its use of computer-based tutorial are, at the least, the equivalent of traditional instruction.

Student Attitudes Concerning Use of Computer-based Lessons Anonymous student opinion regarding the design of the course and, specifically, the use of computer-based techniques as an essential element is shown in Tables IV and VI. In Table IV, positive attitudes are given by a majority of the students on four of five items, particularly those relating to assistance in learning provided by the computer lessons. These attitudes were verified in a follow-up evaluation 8 weeks after the semester ended. Emotional extremes at both ends of the spectrum seem less apparent in the follow-up study. The one initially negative response (an apparently bimodal distribution of answers to Question 2 concerning the equivalency of time required for one-lecture vs one-computer-based-lesson) is a legitimate response supported by the actual computed time used by students to complete average lessons successfully. (See Time Required below.) However, the longer time period required to complete a computer-based lesson is probably a function of the minimum achievement level defined for each lesson (85% satisfactory performance), and of the fact that many students came unprepared to their first interaction with each lesson (i.e., many students used the computer tutorial as introductory work prior to text study, and, then, subsequently repeated the lesson after completing the assigned study materials). This phenomenon is common in most traditional lecture courses. Students often use the lecture as an introduction to the text, even when assigned reading in the text is supposed to precede the lecture. What instructors rarely have an opportunity to do, however, is require students to sit through the lecture a second time for effective learning after they have completed the reading. Although, originally, students were perhaps somewhat justifiably angry about the extensive time demands, they have apparently begun to recognize their own responsibility for the extra time required when they chose to use the computer lessons as introductions to the text. In the follow-up attitude study, the bimodal distribution observed for responses to Question 2 reflects a somewhat positive attitude change. Of the three groups examined, one group of students who completed the experimental course with a grade of C or better and who are now enrolled in Chemistry 818b with the instructor of the experimental course gave a generally positive response; students from the experimental course with comparable grades who transferred to a traditional Chemistry 818b section responded more negatively; and, perhaps most interesting, the group now repeating the introductory course in a traditional section is strongly divided in their response, with a significant majority actually agreeing to the time equivalency. It should be noted that the majority of Chemistry 818b transfer students cited schedule preferences and conflicts as primary reasons for their transfer, although some did indicate that they expected less time and effort would be required by a more traditional class. Table V reflects this phenomenon. When asked in the follow-up questionnaire to respond to the similarity of grade distributions for the experimental and traditional sections, a substantial part of the transfer group showed surprise.

In all three groups, students indicated a preference for the areas of nomenclature, reactions, synthesis, and spectral interpretation as being well-suited for computer-based lessons.

In the original and follow-up evaluations,[a] the three groups gave essentially identical responses in listing advantages of the computer-based lessons. They were overwhelmingly in support of the individual, self-paced, tutorial drill approach which these lessons allowed; and, in general, they repeatedly praised the active student participation level encouraged by the lessons. In this regard, the instructor noted an unusual level of positive excitement and anticipation among the students throughout much of the semester which sharply contrasts with the sense of oppression commonly encountered among organic students. It is possible that it was only the novelty of a new, "educational toy" which buoyed their interest and excitement, but the observable effect made the classroom significantly more pleasant a place in which to lecture.

---

[a]Student comments describing their general feelings about computer-based instruction in organic chemistry were also solicited (as part of the questionnaires). The authors interpreted these comments as an indication of the successful use of computer-based instruction in the experimental course. However, additional evaluation of these responses was deemed appropriate; accordingly, the authors requested that Professor David W. Brooks of Texas A & M University evaluate these student comments, utilizing the methods he described in his contribution to the Symposium on Student Evaluation of Chemistry Courses and Professors via Questionnaires, 165th ACS National Meeting, Dallas, Texas. Professor Brooks concluded that the student responses constituted a positive and meaningful evaluation of the instructional role played by the computer-based lessons in the experimental course.

Disadvantages of computer-based instruction that were cited included the time required to complete the computer-based lessons successfully, difficulties in scheduling extra interactions with difficult lessons (a shortage of teletype terminals during popular hours), certain idiosyncrasies within individual lessons that failed to recognize an acceptable correct response, and problems with the computer system hardware that necessitated the postponement of scheduled interactions with the lessons (see, also, Table V).

Student Attitudes Concerning the Overall Approach Used in the Experimental Course Examination of Tables VI and VII illustrates that average responses solicited just prior to the final examination in the experimental course and average responses some 8 weeks later show general approval of the course design and the computer-based lessons. More interesting is the fact that the collection of small trends is largely in the direction of greater approval with distance.

However, it should be noted that while suggesting the experimental course approach seemed, cognitively, reasonable and justifiable (see Tables VI and VII), many students were emotionally distressed by the extensive time and active learning efforts required of them. Their rancor was directed largely at the instructor (Table VII and individual comments which accompanied the formal university evaluation), although this emotional response, too, appears to be lessening with distance.

Time Required Table IX contains data concerning the computer time required and cost figures for the semester. A total of 2,082 jobs requiring 1,490 computer contact hours for the students occurred in the semester. On the average, about 1.6 interactions were required per lesson per student for a successful completion. This is the equivalent of about 43 minutes per job, and, assuming that one job represents one lesson, about 70 minutes for a successfully completed lesson.

Costs Computer costs are based upon a rate of $260.00 per TM hour (a combination of central processing (CP) and peripheral processing (PP) time) and a line connect charge that was originally $0.50 per hour but was reduced in the 10th week of the semester to $0.40 per hour. A total of 7.21 TM hours costing $1875.10 and $667.65 for connect time were required for the 2,082 jobs. These figures correspond to approximately $1.71 per student terminal hour or $1.99 total cost per successfully completed lesson per student. It is very important to note, however, that a rate of only $26.00 per TM hour is charged at the departmental level within the University system. Had funds for this project come directly from the Chemistry Department teaching budget (rather than a research account), the total cost would have been about $0.58 per student terminal hour.

Instructor's Evaluation (The authors believe it is most appropriate for P. L. S, to comment directly in this phase of the evaluation.) I feel the experimental approach was a success in many respects. Students demonstrated active, inquisitive effort and kept to a minimum the usual complaints concerning the unreasonable demands organic chemistry places on its students. I am, for the first time in five years, satisfied that the grades I assigned at the conclusion of an undergraduate chemistry course are, for the most part, an accurate and well-deserved representation of what the students have learned. I felt useful in the classroom. Rather than feeling limited by the necessity of simply providing a condensed version of some text, I felt able to engage in teaching--that is, in providing a thought-provoking and informative environment in which students can choose to learn.

However, when faced with the difficult task of deleting about one-third of my normal classroom objective content so that the computer lessons might deal with this material via one-to-one tutorial methodology, I recognized that I must in the past have been lecturing at a phenomenal rate, covering information at a pace so rapid that information could be taken down but not simultaneously processed by the students. This realization convinces me that what students of our organic course have been saying for years is true: we demand an excessive amount of work from them (even in traditional training courses). Both my students and I strongly believe that it would be appropriate to extend introductory organic chemistry to three semesters (with 9 hours total credit) or to offer in the first semester of a two-semester course a modification of the experimental course in which three lectures per week, one four-hour laboratory, and computer-based lessons (equivalent to a fourth lecture) would be included for a total of 5 credit hours.

Finally, a word about completely self-paced instruction for organic chemistry. From my experiences last semester, I believe that the nature and multi-dimensional complexity of the content of introductory organic chemistry do not allow for further extensive modularization. Units of study, such as chapters in a text, can be well defined with appropriately described goals and methodology. But organic's unique problem is not the need for further modularization; it is, rather, the opposite. It is the necessary and difficult task of correlating and synthesizing these many units into a single construct, of recognizing a multitude of different interconnections between any collection of individual units, and of solidly developing a complex structural interdependence of all units to support the total, internally consistent structural entity which we call organic chemistry. All this suggests to me that no simple introductory organic course can be fashioned which will allow an average student to achieve completely self-determined and self-paced learning in the field within a reasonable time period. I believe that live interaction with a lecturer and with a scheduled series of lectures is probably a quite necessary learning aspect, if students are to complete an introduction to organic chemistry in two or three semesters. But I am certain that active student participation in the learning process, including as large a degree of self-pacing as is possible, can substantially improve the learning environment. In this regard, modularized computer-based tutorial lessons appear to be an effective, perhaps essential, adjunct to chemical instruction. For, after five years of unsuccessful attempts to convince my undergraduates that an organic text should be their primary information source, I can call your attention to Table VIII with some satisfaction.

Summary

An experimental course in first semester undergraduate organic chemistry was designed to incorporate now-documented computer-based instructional techniques. The design included required computer-based lessons that provided tutorial drill and practice and simulated experiment and reaction applications. Most of the lessons required a minimum achievement level of 85 percent for credit. Since much of the routine instruction was accomplished within the computer lessons, it was possible to reduce the number of formal lectures per week from three to two, but simultaneously to increase the amount of time and detail devoted to theoretical concepts such as bonding, structure, stereochemistry, and reaction mechanism.

Division of lecture responsibility between formal lecturer and computer-based lessons in the experimental approach appears to have developed a greater-than-normal amount of self-reliance, independence, and responsibility from students; the phenomenon is exhibited in student evaluations by the unusually high importance they assigned the text as a primary information source.

Evaluation of the experimental course by comparison with three courses taught by more-traditional methods, including one taught by the instructor of the experimental course, indicated the experimental course approach is, academically, equal to, or better than, traditional methods. Positive student attitudes and opinions concerning use of computer-based lessons as an essential and pedagogically valuable part of the experimental course were received.

Finally, the experimental course and its evaluation have convinced the authors of the following: that students can be encouraged to take a more responsible and aggressively active part in their own organic chemical instruction; and further, that although comprehensive understanding of introductory organic chemistry can, seemingly, be developed in two semesters (by either the experimental or traditional approaches), both approaches place unusually high time demands on students for satisfactory progress.

Acknowledgments

This study was conducted through the assistance and cooperation of the Organic Chemistry Division of the Department of Chemistry, University of Texas at Austin. Funds to pay for computer time, for development of certain computer lessons, and for related personnel were provided by Project C-BE under the direction of Dr. J. J. Lagowski and Dr. J. J. Allan, sponsored jointly by the University of Texas at Austin and the National Science Foundation. Additional funds to pay for development of modules and for personnel were provided by the Moody Foundation and Esso Educational Foundation. The generosity and support of all is hereby gratefully acknowledged.

References

1. Rodewald, L. B., Culp, G. H., and Lagowski, J. J., J. Chem. Educ., 47:134 (1970).
2. Smith, S. G., J. Chem. Educ., 47:608 (1970).
3. Culp, G. H., and Castleberry, S. J., Sci. Ed., 55:423 (1971).
4. Culp, G. H., and Lagowski, J. J., J. Res. Sci. Teach., 8:357 (1971).
5. Smith, S. G., J. Chem. Educ., 48:727 (1971).
6. Venier, C. G., and Reinecke, M. G., J. Chem. Educ., 49:541 (1972).

Table I

Assigned Computer Lessons for Experimental Section of Chemistry 818a

	Name	Area
1.	OCH16	Valence Bonding and Organic Compounds
2.	OCH34	Classes of Organic Compounds
3.	OCH1	Alkane Nomenclature
4.	OCH22	Separation via Extraction
5.	OCH18	Chlorination of Propane
6.	OCH24	Basics of Stereochemistry
7.	OCH2	Alkene Nomenclature
8.	OCH14	Dehydration of 2-Methylcyclohexanol
9.	OCH10	Preparations and Reactions of Alkenes
10.	OCH31	Reporting Laboratory Results
11.	OCH17	Elementary Alkene-related Syntheses
12.	OCH14	Arene Nomenclature
13.	OCH19	Mechanism of Electrophilic Aromatic Substitution; Orientation; Reactivity
14.	OCH11	Preparations and Reactions of Arenes
15.	OCH6	Elementary Aromatic Syntheses
16.	OCH7	Aromatic Syntheses
17.	OCH3	Alcohol, Aldehyde, Ketone Nomenclature
18.	OCH12	Preparations and Reactions of Alcohols
19.	OCH29	Preparations and Reactions of Phenols
20.	OCH32	Elementary NMR Interpretations
21.	OCH33	Elementary IR Interpretations

Table II

Semester Grade Distribution for Chemistry 818a

Year	Lecturer	A	B	C	D	F	F[a] (abs)	Q[b]	X[c]	SAT (Verbal)	SAT (Math)
Fall 72[d]	X	11	16	23	15	4	4	25	2[e]	549	629
Spring 70	X	12	13	16	20	9	0	16	13[f]	558	639
Fall 72	Y	9	22	20	15	13	0	20	0	-	-
Fall 70	Z	7	17	22	12	16	13	14	0	-	-

Grades (%) cover columns A through X.

[a]Absent from class and final exam, but failed to drop the course officially

[b]Dropped the course without penalty (work satisfactory at time of drop)

[c]Incomplete grade assigned

[d]Experimental course

[e]Students are actively engaged in completing small amount of remaining course work (course work already completed is passing).

[f]Small number of these students subsequently completed course satisfactorily; most allowed grade of X to lapse into F after four months.

Table III

Laboratory Grade Distribution for Chemistry 818a[a]

Year	Lecturer[b]	A	B	C	D	F
Fall 72[c]	X	35	44	21	0	0
Spring 70	X	23	40	29	8	0
Fall 72	Y	29	35	29	7	0
Fall 70	Z	22	34	42	1	1

Grades (%) cover columns A through F.

[a]For students completing the course

[b]Lecturer conducted formal lecture part of course; laboratory instruction and grading performed by other personnel

[c]Experimental course

Table IV

Student Attitudes Concerning Computer-based Lessons[a]

Item	Opinion (%)[b] Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Computer techniques are good study aids	$\frac{3}{2(0-0-9)}$	$\frac{3}{5(4-8-9)}$	$\frac{2}{2(0-0-9)}$	$\frac{54}{57(59-46-64)}$	$\frac{37}{33(37-46-9)}$
2. The time required for these lessons was the equivalent of the traditional 3rd formal lecture	$\frac{17}{15(7-23-27)}$	$\frac{44}{29(26-54-9)}$	$\frac{12}{8(11-0-9)}$	$\frac{23}{45(56-15-55)}$	$\frac{3}{2(0-8-0)}$
3. The lessons have helped me learn	$\frac{3}{0(0-0-0)}$	$\frac{2}{2(0-9-0)}$	$\frac{9}{13(7-9-36)}$	$\frac{53}{57(67-46-45)}$	$\frac{33}{27(26-38-18)}$
4. I have enjoyed the lessons	$\frac{11}{5(0-9-18)}$	$\frac{5}{8(7-15-0)}$	$\frac{22}{21(26-23-9)}$	$\frac{36}{55(56-38-73)}$	$\frac{26}{10(11-15-0)}$
5. I would use this type of study aid in other courses if it were available	$\frac{7}{4(0-0-18)}$	$\frac{5}{0(0-0-0)}$	$\frac{28}{13(15-23-0)}$	$\frac{40}{68(70-62-73)}$	$\frac{19}{14(15-15-9)}$

[a]Voluntary anonymous responses were solicited from students immediately prior to final examination (56 responses), and eight weeks after end of course (51 responses). Note that there may be some variation based on difference in students who chose to respond.

[b]% opinions tabulated as shown: $\frac{{}^1n}{{}^2n(S_{SKB}-K_{SB}-B_{SA})}$

where ${}^1n$ = % of 56 voluntary responses received prior to examination

${}^2n$ = % of 51 voluntary responses received 8 weeks after end of course

${}^2n$ is further broken down into

S_{SKB} % of total responses from experimental group taking second half of course (818b) with instructor of experimental course

K_{SB} % of total responses from experimental group taking second half of course (818b) with another instructor

B_{SA} % of total responses from experimental group repeating course (818a) with another instructor

Table V

Voluntary Anonymous Responses to Follow-up Questionnaire[a]

Item	S_{SKB}	K_{SB}	B_{SA}
Attitude towards grade distribution (%)			
The grade distributions for all Chemistry 818a courses taught in Fall of 1972 were about the same. Is this:			
About what you expected?	54	31	55
A surprise to you?	13	31	27
Of little concern to your expectations?	33	38	18
System problems (%)			
How many problems did you have with the Taurus System?			
Many	4	8	18
Occasionally	85	92	73
None	11	0	9
Program problems (%)			
How many problems did you have with errors in the computer lessons?			
Many	7	0	9
Occasionally	85	85	82
None	7	15	9

[a]For an interpretation of notations S_{SKB}, K_{SB}, and B_{SA} please see note b, Table IV.

Table VI

Additional Questions for Formal University Student Evaluation (Anonymous and Voluntary) of Experimental Course and Instructor

For Following Questions

Answer:	Definitely Yes	Yes	Uncertain	No	Definitely No
	+2	+1	0	-1	-2

Did the use of computer-based instruction help you discover and use your own pace for learning organic chemistry?

$(\bar{X})^a$ = .4[.7](.8)

Do two formal lectures per week plus regular computer-based lessons seem to provide sufficient explanation of subject matter for a self-paced introductory course in organic chemistry?

$(\bar{X})$ = -.7[-.5](-.2)

Is it fair to ask students to teach themselves organic chemistry from a selected textbook aided by formal lectures and computer-based lessons?

$(\bar{X})$ = .2[.5](.8)

If this course had been composed of three formal lessons per week and <u>optional</u> computer-based lessons, would you have devoted as much time to studying the computer-based lessons as you did this semester?

$(\bar{X})$ = .4[.2](.2)

Did you find working on the computer-based lessons an enjoyable way to learn organic chemistry?

$(\bar{X})$ = .6[.8](1.0)

Do you think it is accurate to say that the textbook presents an introduction to organic chemistry organized descriptively according to functional groups, while the formal lectures seem to present a broader, more theoretical organization according to organic structure and reaction mechanism?

$(\bar{X})$ = .9[.8](1.0)

Should a combination of computer-based instruction and formal lectures (such as used this semester) be used in future courses to help students learn organic chemistry?

$(\bar{X})$ = .9[1.0](1.2)

---

[a] Average responses indicated as $^1n[^2n](^3n)$

where ^1n shows average of 61 responses obtained immediately prior to final examination

^2n shows average of 52 responses obtained 8 weeks later both from students currently enrolled in second half of organic chemistry (818b) and from students repeating first half of organic chemistry

^3n shows average of 37 responses of students currently enrolled in 818b only

Table VI continued

For Following Questions

Answer:	most of the time	a good part of the time	some of the time	a small part of the time	never
	+2	+1	0	-1	-2

Have you resented being part of this experiment which is trying to define new ways of presenting subject matter in an introductory organic chemistry course?

$(\bar{X})$ = -1.0[-1.2](-1.4)

Were you able to correlate the two different organizational approaches used in the text and in formal lectures?

$(\bar{X})$ = .4[.2](.5)

If you think back over the feelings you had while completing the required computer-based lessons, do you believe you were usually trying to learn and understand the content of each lesson (instead of just trying to get through one more assignment)?

$(\bar{X})$ = .5[.6](.8)

Table VII

ANONYMOUS STUDENT RESPONSES TO PERTINENT QUESTIONS FROM FORMAL UNIVERSITY EVALUATION[a]

A comparison of average responses ($\overline{X}$) of students in experimental course and in traditional course taught by same instructor 30 months earlier

	Spring 1970		Fall 1972		
	Control	Limited CAI access	Before final exam	Eight week ($S_{SKB}+K_{SB}+B_{SA}$)	follow-up ($S_{SKB}+K_{SB}$)
scale: Def. Yes +2, Yes +1, Neutral 0, No -1, Def. No -2					
expected to enjoy course	.6	1.1	.6	.6	.7
instructor well-prepared	1.0	1.4	.9	1.0	1.2
well-paced course	-1.0	-1.4	-.5	-.1	0
adequate text	1.2	1.3	1.1	1.0	1.4
expected course to be of value			1.1	1.2	1.4
found course of value to date			.9	.8	1.2
scale: One of best +2, Above ave. +1, Ave. 0, Below ave. -1, Far below ave. -2					
comparison with other instructors	1.0	.7	.2	.4	.6
comparison with other courses	.8	.7	.6	.7	.9
scale: Far more than expected +2, More than expected +1, Expected 0, Less than expected -1, Far less than expected -2					
comparison of course with original expectations	.5	.3	.2	.1	.3
scale: Well above ave. +2, Above ave. +1, Ave. 0, Below ave. -1, Well below ave. -2					
student effort in course	1.2	1.3	1.4	1.3	1.4

[a] For an interpretation of notations S_{SKB}, K_{SB}, and B_{SA} see Table VIII.

Table VIII

Student Ranking of Contribution to Learning of Organic Chemistry

Students were asked to:

Rank the following in the order which you feel would most contribute to learning organic chemistry. Rank the most important as No. 1 and the least important as No. 5.

___ Textbook
___ Formal lectures
___ Question and answer discussion period
___ Laboratory (including laboratory lecture)
___ Computer-based lessons

Averaging their responses for each item gave the following order (questionnaire administered before final examination):

Text
Computer
Lecture
Lab
Q-A Period

($\overline{X}$) average ranking on anonymous follow-up questionnaire[a]

S_{SKB}	K_{SB}	K_{KB} (control)	B_{SA}
1.37-text	1.46-text	1.29-lecture	1.36-text
2.04-lecture	1.92-lecture	2.13-text	2.27-lecture
3.11-computer	3.58-computer	3.16-Q-A period	3.27-computer
4.00-lab	3.85-Q-A period	3.95-lab	4.00-lab
4.44-Q-A period	4.27-lab	4.32-computer	4.09-Q-A period

[a] S_{SKB} = students from experimental group now taking second half of course (818b) with instructor of experimental course

K_{SB} = students from experimental group now taking second half of course (818b) with another instructor

K_{KB} = students with no exposure to experimental course, now enrolled in second semester (818b) with another instructor

B_{SA} = students from experimental group now repeating course (818a) with another instructor

Table IX

Time Required and Cost of Interactions

Number of jobs (sign-ons) run: 2,082

Hours of computer connect time: 1,489.89

Computer TM* hours: 7.21

Computer TM charge: $1,875.10

Computer connect time charge: $667.65

Hours per successfully completed module: 1.17 (70 minutes)

Cost per successfully completed module: $1.99

Cost per student-terminal hour: $1.71

*TM hour includes central processing time and peripheral processing time.