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AUTHOR Lower, Stephen K.
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INSTITUTION Simon Fraser Univ., Burnaby (British Columbia). Dept. of Chemistry.
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ABSTRACT

Both failures and successes have been experienced in the application of the computer to the teaching of introductory chemistry at Simon Fraser University. Chemistry teachers looked to computer assisted instruction (CAI) to improve instruction because CAI effectively dealt with chemical concepts and their practical application and with the wide range of students found in freshman chemistry. Initial CAI short courses failed after the novelty wore off, but an effective CAI problem tutorial--CHEMEX--was designed. Students used it because it met their specific individual needs. A later program--ALCHEM--which consisted of interactive exercises on various chemical principles was less well received by the students, apparently because they did not perceive the usefulness of the exercises. The newest program, a fully individualized CAI course with specific learning objectives for each unit, has been well received by the students and eliminated student failures during its initial semester. In summary, the success of CAI appears to be related as much to the degree of individualization and attention to their needs as perceived by the students as to the quality of the programs themselves. (PB)

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Stephen K. Lower

Department of Chemistry
Simon Fraser University
Burnaby 2, B.C., Canada

(604) 291-3353



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Stephen K. Lower
Department of Chemistry
Simon Fraser University
Burnaby 2, B.C., Canada

In this article, I should like to review both the failures and successes we have experienced during the five years that we have been applying the computer to the teaching of introductory Chemistry. Most of this activity has taken the form of direct, interactive computer-assisted instruction, but I will not dwell upon the details of the instructional programs themselves. I wish to focus instead on the much more general and significant question of how computer-mediated learning can be most effectively employed in the context of the overall course. I believe that the viability of c.a.i. will ultimately depend on our ability to demonstrate its cost-effectiveness, and that a special effort must be made by teacher-users to help achieve that end.

Chemistry is typical of many science-oriented disciplines in that it encompasses a large number of concepts that are useful only insofar as they can be applied to various concrete situations. While passive reading and classroom experience can help convey some of the necessary background material and place these concepts and principles in their proper perspective, real facility in making practical use of them can only come through.

practice and exercise in doing just that. This, together with the wide range of background, interest, and aptitude characterising the clientele of a typical Freshman course, has made chemists as a group traditionally active in seeking out innovative and more effective teaching methods.

Thus shortly after Simon Fraser University first opened its doors in 1965, we had commenced exploring the use of audiotapes, lecture-theatre response systems, and the Postlethwait concept of booth-laboratories (1,2). Our entry into c.a.i. occurred in 1969, when IBM's Coursewriter III system (3,4) was implemented by our Computing Centre. At first, various faculty members tried their hand at authoring short "courses" on subjects such as the gas laws, balancing equations, error analysis, and the like. Later, more extensive courses on exponential arithmetic, logarithms, and organic nomenclature were added.

Although these courses received considerable use initially, this usage soon dropped off as the novelty effect disappeared for both the students and the faculty. After six months the terminals were mostly deserted, and served mainly as showpieces for visitors. In retrospect, the direct reason for this failure of our early efforts is starkly obvious: we didn't really know what we wanted to do with c.a.i.; it was regarded by the faculty as just another teaching "aid", and thus by the students as just more "extra work".

We then tried a somewhat different approach. For several years I had been preparing tape-recorded commentaries on the weekly problem sets that students are given in most chemistry courses. These tapes were well-received and apparently had some effect on student performance (5); it seemed reasonable that c.a.i. could serve the same need even more effectively, owing to its interactive nature and branching capability. A pilot "problem-tutorial" program was written, and achieved considerable success: students were using it, and c.a.i. was saved from a premature death. For several years now, our CHEMEX program, as it is called, has been the most heavily used of all the programs on our system. It is designed so that students can receive computer-mediated assistance on any of some 60 problems covering the usual topics of introductory Chemistry. The problems themselves, which are contained in a printed booklet, can either be assigned as "homework" exercises, or used as examples for similar problems that are assigned from other sources.

The reasons for the popularity of CHEMEX are fairly obvious: a student comes to the program for help on a particular problem. His readiness to understand and master whatever principles are involved is at a peak; he is motivated, and has a reasonable expectation of receiving the help he needs, within the time he has allotted himself. In short, the students apparently feel that CHEMEX meets a real need.

Two years ago, we began a somewhat different type of c.a.i. program, consisting of highly interactive exercises on various basic chemical principles, all arranged in a modular form to permit maximum flexibility in their use. While many teachers consider this program ("ALCHEM") to be considerably "better" than CHEMEX, it receives comparatively little spontaneous student use. Clearly, students do not generally have a burning desire to "do exercises", no matter how beneficial to the soul this may be.

Do these programs "work"? Are they successful? If we have learned only one thing in our experience with c.a.i., it is that the effectiveness of the medium depends as much on the manner in which it is used, as on the quality of the instructional programming itself. If the course is given in the strictly "traditional" manner, with the instructor's emphasis being on his three lectures per week, then c.a.i. is unlikely to make a significant impact on the course or on the success rate of the students. If, on the other hand, the instructor clearly defines the role that c.a.i. is to play, and adjusts the other aspects of his course to complement that role, then c.a.i. can become extremely effective. If this effectiveness is to manifest itself, a certain "critical mass" of c.a.i. material must be available so that a significant portion of the total course can be covered; only then will c.a.i. begin to make possible the radical changes in teaching and learning that it ultimately promises.

It was not until the summer of 1972 that I felt we were beginning to reach the point where we could really do something different. For that semester, I designed a Freshman course based largely on the "individual study" method. Each segment of the course was defined in terms of specific learning objectives that the students were expected to achieve, and would be tested for. Each list of objectives was accompanied by a list of "sources" or aids that the student could employ for help in achieving these objectives. These sources always included specific reading and problem assignments, and usually some audio-tape and c.a.i. material. Completion of the ALCHEM c.a.i. sequences was made a "requirement" of the course, since this, in itself, would demonstrate a certain level of mastery of specific course objectives.

Since the bulk of student learning was effectively decoupled from formal class meetings, the number of these could be reduced. I gave only one, instead of the normal three lectures per week, and I was able to devote this time to what I believe to be the proper function of lectures: to show why the various topics of chemistry are important, how they fit into the context of chemistry and science in general, and to bring in the cultural and humanistic aspects of the subject. Thus in the lecture portion of the course, I hope to stimulate and motivate, to convey my enthusiasm for the subject; I doubt that I could ever do this through c.a.i. or any other medium.

Did the students learn more? Not really; our summer-semester classes are too small for statistics to have much meaning, but there were no more A's or B's than I normally give. On the other hand, there was not a single D or F grade: for the first time ever in my teaching of a Freshman course, there was not a single failure! Best of all, the reaction of the students was overwhelmingly favorable; they liked knowing exactly what they must learn, and on what basis they would be evaluated. Since I no longer had to prepare three lectures per week, I was able to devote more time to students who needed special help, and could also conduct my own tutorial sessions, instead of relegating this job to a graduate student.

In this case, I feel that c.a.i. has indeed been a "success". But what has really succeeded here is not c.a.i. itself, but the concept of an individual-study course, utilizing the best features of a variety of learning aids in a comprehensive manner. The significance of c.a.i. and audiotapes is that they make this teaching approach feasible. It remains to be seen whether other teachers can or will adapt this approach, or whether it could be made to work with much larger classes.

Where do we hope to go from here? For the moment, the task of continually revising and updating existing program material competes seriously with getting more material written, but both must be done; we still have much less than we really need.

Our Computing Centre, which gives admirable support to c.a.i. in the face of all the competing demands that a university places on computing resources, is about to implement a consolidated on-line system that will provide c.a.i., remote job entry, conversational computing (APL), and information retrieval, all though the same terminal system. This will increase the possible level of sophistication in our c.a.i. programs by a considerable degree, and open up a number of new uses of the computer for both students and teachers. We will also be able to make the power and flexibility of interactive graphics available to c.a.i., thus extending the scope of c.a.i. into a number of areas that we cannot adequately serve with typewriter terminals.

For a relatively small institution such as ours, which can never expect to become self-sufficient, c.a.i.-wise, in more than a few subject areas, the matter of exchange of program materials is an important one. It is expected that our new system will be able to simulate most of the principal authoring languages, since it is being designed to meet the functional specifications recently set forth by the National Research Council of Canada[7] for c.a.i. authoring languages; these specifications exceed the capabilities of all the principal existing languages, including Coursewriter, TUTOR, and PLANIT. At the present time, our ALCHEM and CHEMEX[6] programs are implemented at twelve institutions in North America; to facilitate further

exchange of this kind, we are considering the use of a machine-independent c.a.i. documentation language, such as the Primary Author Language ("PAL") that has been developed by P. Ripota(7) in West Germany.

It is only comparatively recently that terms such as "cost-effectiveness" and "productivity" have been applied to college teaching (although practically never by the teachers themselves!). Like it or not, we are bound to hear much more about these subjects as university budgets shrink in relation to the other escalating demands on the public purse. While c.a.i. may be allowed a reasonable incubation period, those of us who are making substantial demands on computer resources in connection with our teaching must soon be prepared to demonstrate that this use is yielding equally substantial returns in the form of increases in the rate or extent of student learning, andalso in teacher productivity. In short, the computer must truly"make a difference" if it is to survive as a mainstream learning tool.

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