Mainline CAI, necessary but not oppressive*

by C. VICTOR BUNDERSON

University of Texas
Austin, Texas

Two years ago the term "mainline instruction" was introduced as a referent to a carefully designed, total instructional system to replace complete courses with a far less labor-intensive mixture of men and machines. This mode was contrasted with the adjunctive use of the computer by faculty members who are happy to work within the system and merely want to use the computer to improve their instruction. The two NSF-sponsored conferences on Computers in the Undergraduate Curriculum have illustrated and stimulated the adjunctive approach.

The term "mainline instruction" is not fully descriptive of the concept it designates. It serves as a shorthand term for individualized instructional systems of major scope, using the computer as a tool for instructional management and information transmission, developed according to a design science approach and used as a less costly alternative to conventional instruction. The ends to which computer uses are directed in this mode are necessarily controversial for:

1. mainline instructional systems revise the role of the teacher substantially,
2. mainline systems imply the emergence of a new profession of "courseware design" backed by instructional scientists who develop the instructional theorems used by the courseware designers, and
3. it is feared by some that the transformation of education from labor-intensive to technology-intensive systems might be accomplished only at the sacrifice of certain values of our liberal education tradition.

Advocates of the adjunctive use of computers in education point out that their approach bypasses these controversial aspects of the more radical mainline approach. By leaving the teacher firmly in control they minimize the threat to members of that profession, and more easily avoid charges of "dehumanization." By pointing out that no generally accepted theory of instruction exists, nor ready translations of learning psychology to instruction, they keep the teacher in control of program development and put off the problem of standards for evaluating programs. Because of the merits of the adjunctive mode in opening instruction to more student-oriented, problem-solving approaches, they can argue that adjunctive computer use in instruction not only preserves important values of our liberal tradition, but enhances them.

Arthur Luehrmann has been one of the more articulate and positive advocates of the adjunctive approach. Among the values to be sought through this mode are the following:

1. to bring about a qualitative restructuring of the curriculum toward algorithmic and problem-solving approaches, and
2. to encourage independent, self-motivated learning, and investigation using the computer as a tool.

A third value should be added to this list, for Luehrmann and his colleagues at Dartmouth have been leaders in this effort for years—

3. to bring about widespread and flexible access to computer use in higher education nationally consonant with the recommendations of the Pierce report.

My intention in writing this paper is not to challenge these values, for I share them. It is not to argue that the adjunctive approach is not a good way to seek the three goals listed above, for I believe it is and that it will be the more visible way to achieve them for the next few years, touching many more students than will mainline CAI. My purpose in this paper rather is to present data and rationale supporting the propositions that:

1. mainline systems are necessary for the widespread dissemination of computers throughout the educational establishment; and

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(2) that contrary to stereotypes built up through comparison with earlier attempts at tutorial CAI, mainline systems can lead to the first two goals listed above and need not detract from other important values of liberal education.

THAT MAINLINE SYSTEMS ARE NECESSARY

The Pierce report recommends that steps be taken to provide all college and university students needing such services with adequate computing services. It does not specify how this is to be done. A direct investment of the Federal Government to support the free and relatively unstructured use of computers in the adjunct mode would represent a staggering capital investment. The government has not risen to this challenge. To examine some reasons for their reluctance to do so, the need for computers must be put in context with other problems being faced by education in this country which also demand additional capital. Some of these problems are accompanied by compelling arguments for higher priority than the Pierce report recommendations.

Colleges and universities are facing serious financial problems and social pressures which call for rapid and dramatic change. Consider the following facts. During the past ten years, the gross national product increased 93 percent. During the same period, the cost of higher education increased 266 percent. An ever-increasing percentage of this rise was attributable to faculty salaries. Instructional outlays accounted for 45 percent of the costs of higher education in 1945. In 1971, they accounted for 65 percent. Approximately 90 percent of instructional costs are attributable to faculty salaries.

While salaries have been increasing, productivity, as expressed by teacher-pupil ratios, has been decreasing. In 1959-60, the ratio was one teacher to 26 students in higher education. In 1969-70, it was 1 to 20.

In an analysis of population trends for the 100 largest standard metropolitan areas, the Academy for Educational Development10 projected that the population of 18-24 year olds will increase from 12.5 million to 15.7 million between 1968 and 1990 (26 percent). During this same period of time, however, collegiate level enrollment was projected to increase from 4.1 to 8.2 million, or 100 percent. This increase reflects increasing numbers of disadvantaged youth entering college, increases in married women returning to school, more employees upgrading skills, more technical and vocational education, and more leisure time due to automation. The cost estimate for this greatly increased body of students is $24 billion in 1990, up 200 percent from the $8 billion cost in 1968. This estimate covers operating costs alone. It does not reflect capital construction nor athletics.

Legislatures, state and federal, are refusing to support these trends. In an attempt to help beleaguered college presidents meet the resulting cost squeeze, the Academy for Educational Development listed 115 ways to decrease the costs of higher education. First on the list was reducing the number of non-tenured faculty, adjunct or part-time faculty, consultants, and research and teaching assistants. Another suggestion was to cut computer costs or postpone the acquisition of new hardware. However, if CAI could be shown to be a cost-effective alternative to more labor-intensive methods, college presidents would have many more options, including, in some cases, the option to increase enrollment and effectiveness simultaneously.

Clearly, radically different approaches to education are needed. It will not be possible economically to continue the teacher/classroom model indefinitely as the prime method in higher education. Peter Drucker4 has expressed this thought as follows:

The educators still talk of minor changes, of adjustments and improvements. Few of them see much reason for radical changes. Yet education will in all likelihood be transformed within the next decades by giant forces from without.

It will be changed, first, because it is headed straight into a major economic crisis. It is not that we cannot afford the high costs of education; we cannot afford its low productivity. We must get results from the tremendous investment we are making . . . .

Teaching is where agriculture was around 1750, when it took some 200 men on the farm to feed one nonfarmer in the town. We have to make the teacher more productive, have to multiply his impact, have to increase greatly the harvest from his or her skill, knowledge, dedication, and effort. Otherwise we shall run out of teachers—even if we do not run out of money for education.

It is difficult to see how adjunctive CAI can meet the requirements implied by Drucker for educational reform. The philosophy of adjunctive CAI accepts without question the central role of the classroom teacher. Materials are prepared with teachers in mind to provide the context and motivation for the usage of computer packages. This assures that computer use will represent an add-on cost to existing costs for labor, overhead, and physical plant. It also makes it difficult to disseminate the package widely, for a teacher training project of some kind is necessary to enable the new user to adapt the inductive approach to instruc-
From the collection of the Computer History Museum (www.computerhistory.org)
Young University are developing the courseware for the TICCIT system. This courseware may be described as a set of mainline systems in the areas of freshman mathematics, freshman English composition, remedial English, and remedial mathematics. The target is the junior colleges of this nation. The four mainline systems are designed to replace up to 20 percent of the classroom instruction in the typical junior colleges at less than $1.00 per student hour (instead of the existing $1.50 for instruction, or $3.20 for total costs now extant).

In the development of courseware for the TICCIT junior college project, we are designing novel systems which will enable students to achieve on each of four major kinds of objectives, each measured by special scoring systems implemented in the courseware. These are:

(1) All students will achieve mastery at either A, B, or C level (student contracts for the level) on the lesson and unit tests that make up the measurement system for mastery.

(2) All students will develop a more positive attitude toward the subject matter and mode of instruction as measured by increases in their tendencies to approach voluntarily optional work related to the subject matter. More precisely, we provide opportunities within the course for optional work, use a variety of techniques to encourage approach responses, and measure our success. In some ways, we feel that approach is the master criterion, for it determines the student's future relationships with the subject matter. We can teach him to hate it and avoid it in the future or to like it and approach it in the future. This criterion seems especially important at the junior college level.

(3) All students should develop improved strategies for learning relative to the subject matter and the TICCIT system implementation. Strategies are operationally defined in our courseware as a vector of integers referring to items on one or more menus presented to the student. The order of the integers describes a sequence through the items on a particular menu. Menus exist at the course level, unit level, and lesson level, and serve as hierarchically organized points of control. A strategy may be entered in any of two different modes: survey or instruction. Provision for review is also available.

We will measure our success in improving strategies by changes in efficiency scores (mastery + time) and by reference to strategies found to be effective for certain outcomes by certain classes of students, especially the more effective students. A high-level advisor program will exist to encourage and help students in the selection of good strategies.

(4) We wish students to develop a sense of responsibility for their own learning. We want them to feel that education is their choice and that both the positive and negative consequences of it are to be chosen or rejected by them alone. What we wish to convey to the student is that he is not just the recipient of orders but a participant in decisions that shape his life. He will be given the opportunity to choose a grade level, try various strategies, choose to take optional extra work or not, and choose among various "fun options" (games, films, computation and plotting programs, etc.). From the instructional system and the humans who manage it, the student should get the clear message:

"We provide effective, efficient, and palatable instructional resources and a way of measuring your progress toward your goals. Choosing among alternate goals is your responsibility. Working effectively is your responsibility. If you fall below your potential we provide sympathy and advice. If necessary, we provide automatic control for a time, always encouraging the independence that assures you of control over your own destiny."

Measurement of changes in responsible behavior in the use of learner control options and commands is a complex process and will initially be done only at a gross level. These gross scores will locate the student somewhere between yielding control completely to the program and permitting him to push control buttons wildly or to jump about within the course without making progress on mastery and efficiency.

Such an ambitious scheme can only be attempted within the context of large mainline instructional systems. We estimate that the average student will sit at the terminal for at least 50 hours for five hours of semester credit. The mechanisms we have and are designing to achieve each of these objectives cannot be described in this short paper, but some flavor can be given. Briefly, we seek to achieve these objectives through three major sets of novel approaches which have never been used before, to our knowledge, in any CAI program. These are: (1) new control structures, to facilitate both learner control with program control options, (2) the construction of a high-level "advisor program," (3) the use of a variety of motivational techniques.
CONTROL STRUCTURES AND LEARNER CONTROL

Three years ago The University of Texas CAI Laboratory developed a modestly sized mainline CAI system to teach mathematics prerequisite to freshman science courses. This program employed learner control of sequence, amount of practice, and testing very extensively. Hierarchical index structures, menus, and a separate control program were implemented. A series of research studies was conducted to analyze the effects of various control options (e.g., Judd, Bunderson, and Bessent). These studies were inconclusive regarding the effects of learner control vs. program control on mastery and speed criteria. Though equivocal, the results indicated that little might be lost through the use of learner control in CAI on mastery and speed. It later occurred to us that much might be gained, and that learner control was more likely to be related to measures of approach, strategy, and responsibility than to mastery. Gambling that evaluation will prove us right, but that if it doesn’t the program control options can take over, the control structures developed in the MathS course were revised and improved, and are being implemented in the TICCIT courseware.

Methods of control differ somewhat from course to course and among levels within courses. A number of the important concepts are illustrated in Figures 1 and 2. Figure 1 represents the components of a lesson menu from the precalculus mathematics course. The objectives section tells the students about the structure of the lesson. Those students who opt for this material learn that there are two major supporting objectives, corresponding to the two instructional sequences (items 5 and 6). Section 5 provides structured instruction to enable the student to achieve the objective: Given a second degree polynomial function in standard form, perfect square form, and factored form, identify and plot the extreme point, zeros (if any) and y intercept. Section 6 teaches algorithms for transforming functions from one form to another, and for finding zeros. Within both of these instructional sequences various control options and paradigms derived from recent research and theory in instructional psychology are used. The “Review Tips” section discusses the prerequisites (concept of zero, domain, range, function, etc.), provides brief review material, and references earlier lessons. The “So what?” file contains information on why a junior college student should bother to learn these objectives. The mini-lesson is a quick survey of the entire lesson. Definitions are provided for the important concepts in the lesson, including second degree polynomial and the three forms of the function. The mastery test is diagnostic. If the student fails parts of it he is given advice which is designed to help him go back to the lesson menu, or to review, before taking the test another time.

Figure 2 is a nondeterministic flowchart in which the overall pattern for most lessons is revealed. Students may try several strategies before taking the mastery test, and after failing it the first time. The advisor program may be called by the student for a discussion of various strategies used by fast, slow, and average students, or the advisor program may interject commentary under certain conditions.

Lesson Menu

Second Degree Polynomial Functions

1. Objectives
2. Review tip
3. So what?
4. Mini-lesson
5. Definitions
6. Instruction: zeros, extreme point, y intercept, graphing
7. Instruction: algorithms
8. Mastery test

Figure 1—Sample menu for lesson on second degree polynomial functions

Figure 2—Generalized flow within a lesson
A student is not required to attempt a mastery test more than twice in close succession, but may elect to come back to the lesson at a later time. Under this condition the lesson is automatically rescheduled. The student may request “status” from the advisor program at any time to see what lessons he has completed.

Once the mastery test has been passed, if there is additional instruction at the A and B level, then the student contract is checked, and if he has elected a B or A, additional instruction is given, along with the A-B test. If he has not elected a B or A, a calculation is made to predict what he would probably get on the A-B test. If he is an underachiever who could get a B or A, he is provided with friendly advice and scored for approach if he takes it. He then has a chance to select among the “fun options” which might include such items as “More on that Topic” (which gives him A and B items not seen), a computational plotting program, a game film or a short film (videotapes can be shown on the TICCIT terminal). TIDBITS are historical vignettes, anecdotes, etc., related to the lesson topic, and are scored as approach. The student pays for fun options, using points earned through earlier achievement. The advisor may “advertise” certain options when the student arrives at the fun options menu. If he arrives at the fun options menu without having passed the mastery test, his choices are restricted and his bank account of points is low.

THE ADVISOR PROGRAM

The advisor is simply a set of routines which are either called by the student by depressing an interrupt key and typing a code word, or which are called by the course program at certain points. Four of the functions have been discussed above: strategy advice, status report, A-B advice, and “advertising.” Other functions deal with setting and changing the grade contract, with scheduling reviews, and with keeping track of the “bank account” income and expenses.

MOTIVATIONAL TECHNIQUES

The reader will have observed a number of motivational techniques in the previous discussion. The whole concept of learner control, with emphasis on responsibility and skill in the use of strategies, has the potential of being very motivating to many students. The “So what?” file, the “fun options,” and the point system used to earn fun options are designed to enhance motivation as well as to develop approach. In addition to these techniques, humor, cartoons, graphics, color, and audio are used throughout in an attempt to introduce the light and clever touches which have been used so well in the TV programs developed by Children’s Television Workshop. Professional writers and TV scriptors are a part of the courseware teams. The intimate mixture of short videotapes and CAI sequences is a powerful new mechanism of expression for creative authoring talent, and we hope to learn to use it to the fullest to provide instruction that is palatable and fun as well as effective and efficient.

ON FREEDOM AND PRIVACY

The philosophy of learner choice and the respect for the individual implicit in our courseware design assure individual freedom. An individual is free even to remain antagonistic toward mathematics, or to resist attempts to accept responsibility, for our interactions are all persuasive rather than coercive.

On the issue of privacy, we plan to keep scores on mastery, speed and accuracy, learning strategies, voluntary approach, and the responsible use of control options. These scores are necessary both for the advisor program and for the human advisors to help each student achieve his objectives, and to improve the system for later students. The data are analogous to a combination of a grade transcript and a set of aptitude scores now found in students’ files in registrars’ offices at any college, but these data are more precise and detailed. They could presumably be misused in the same manner as could the registrars’ files if security were lost. IQ scores have been misused and restrictions set up against their distribution. Presumably, appropriate restrictions must also be established to protect the misuse of our courseware scores. Indeed, it is possible to permit the individual to contract for the courseware to attempt to influence strategies, attitude, and responsibility as well as mastery. Such an agreement between the student and the system would be a positive and constructive substitute for the “privacy warning” now given to Dartmouth students whenever a record is kept of certain of their transactions at a terminal.

SUMMARY

Because of increasing cost problems in higher education, and the need to find more cost-effective approaches to traditional instruction, mainline instructional systems were proposed as a desirable alternative. The first reason discussed was economic. Mainline instructional systems, as defined in this paper, replace important subsystems within an educational institution with a less labor-intensive, potentially more cost-effective technology. Any proposal which uses technology as an
adjunct to a classroom teacher, representing an add-on cost, is unlikely to represent a viable alternative in the years ahead unless somehow incorporated within a more radical restructuring of education.

That systematically designed mainline courseware can lead to the qualitative restructuring of curricula, and, in particular, can enhance independent, self-motivated learning and other important values was discussed. An example was taken from the TICCIT courseware development project in freshman mathematics to illustrate this discussion.

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