The computer and thinking skills: Rationale for a revitalized curriculum

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ABSTRACT

Recent reports lament the devaluation of the baccalaureate degree; too often students fail to acquire the thinking skills needed after graduation. Fortunately, the computer, besides offering utilities that increase productivity, can deliver computer-aided instruction (CAI) that helps develop thinking skills by simulating the mental processes of academic experts.

Liberal arts faculty sometimes dismiss CAI because they consider its algorithms too narrow and rigid to serve as problem-solving devices. However, such algorithms should not be viewed as capturing the essence of thinking skills, but as offering simplified problem-solving approaches that students can grasp—approaches that must be supplemented and even superseded by the professor in the classroom.

Despite objections, three recent trends are likely to hasten the advent of courseware that models and develops thinking skills: improved integration of courseware into coursework, increased attention to the ways students learn and experts think, and the introduction of sophisticated authoring systems.
INTRODUCTION

Recent reports by a number of prestigious educational task forces have brought to the attention of the American public a concern professors have recognized for some time: the decline and devaluation of the undergraduate degree. The Study Group on the Condition of Excellence in American Higher Education, the Carnegie Forum's Task Force on Teaching as a Profession, and the Association of American Colleges' Project on Redefining the Meaning and Purpose of Baccalaureate Degrees have all addressed the problem and judged it a cause for national alarm. Among the various manifestations of the decline, the one most frequently cited is this: too often students receive their college degrees without acquiring the thinking skills needed to direct their continuing education or to advance in their chosen professions.

To cure our academic ills and restore vitality to the education of our undergraduates, the commissions on undergraduate education have prescribed a coherent curriculum that subordinates the mere communication of information to the development of a wide range of thinking skills. According to the Carnegie Forum, the “core should develop the essential skills of comprehension, computation, writing, speaking, and clear thinking.” Among the skills deemed most important by the Association of American Colleges are logical inquiry and critical analysis, the processes of literacy (writing, reading, speaking, and listening), manipulating numerical data, understanding the scientific method, and shaping values through choices. Such a curriculum, according to the Association, would constitute “the intellectual, aesthetic, and philosophical experiences that should enter into the lives of men and women engaged in baccalaureate education.”

If we accept this agenda for reform, then we must enlist all the educational resources at our disposal. If the undergraduate curriculum must be reformed, not merely repaired, then educators should not overlook the advantages of the computer.

COMPUTERS AND THINKING SKILLS:
A MODEST PROPOSAL

Besides the use of computer utilities to increase productivity, the computer has another, more controversial use in education. Although the notion seems incongruous to some and anathema to others, the computer can be used to guide students, step by step, through the difficult, iterative thinking processes that characterize mastery of college-level disciplines.

As an example, consider how a student could be taught critical reading, one of the thinking skills most essential for a revitalized postsecondary curriculum. According to the report of the Association of American Colleges, our students need to be taught how to read actively, arguing along the way with every word and assertion; and how to read aesthetically and critically, seeking the word, the expression, the exact form of phrase or direction that catches the reader just when the reader wants to escape... (p. 18)

With the proper lesson, the computer can instruct the student how to read “actively”—either “aesthetically” or “critically” as the student’s discipline demands. Making explicit the steps of the mental processes that an educated individual follows when reading the primary works of a discipline, the lesson would present a central text—a poem in a literature course, a theorem in mathematics, a syllogism in philosophy, an argument in debate—and then guide the student through a careful reading. Slowly, sequentially, the lesson would highlight and explain key points, pause to explore the implications of a phrase, and consider the rationale for analysis; in other words, the computer would simulate the process of careful reading the student needs to master. Furthermore, the computer would engage the student’s attention by its interactivity; testing the student’s comprehension through judicious questions and providing direction through appropriate responses and citations for further study.

Although we often consider speed to be the essence of the computer’s power, in this instance the power would lie in the computer’s potential for slow motion—its ability to advance more measuredly, more circumspectly than the student is inclined, to probe the significance of the text and to explain the steps of the process with sufficient depth and care.

To a seasoned professor, such a lesson might seem stultifying in its slow pace and elementary level. The professor might be eager to advance to topics of great pith and moment, such as the significance of Hamlet; meanwhile the student, just beginning an initiation into the academic discipline, needs to master more elementary skills, such as how to read a Shakespearean play. The professor—upholding high standards, forgetting an apprenticeship from long ago, or simply bored with the basics—may demand the fruits of thinking skills without helping develop and refine the student’s ability to think. The computer, which lacks the capacity for boredom and impatience, can exercise the student at a level well below that comfortable for the professor.

Because we learn best by doing, the computer’s interactive engagement of the student makes it a better device than a textbook for teaching such skills. A text may offer the advantages of lower cost and greater accessibility, but its content (for example, on how to read critically) is likely to be read at least as perfunctorily as young students tend to read their
other assignments. Also, the book’s interactivity is less compelling: it can pose questions, but it cannot withhold answers, judge responses, and provide direction related to students’ responses. By contrast, the computer-based lesson not only describes the process of critical reading, but promotes it. By compelling students to employ the techniques of critical reading, the lesson enhances the possibility that those techniques will be learned. Furthermore, the lesson can impose a regimen of discipline and responsiveness that the student may lack. In the hours after class—the two-thirds of the learning time during which the professor is absent—many students would profit from the imposition of more discipline, rigor, and guidance than solitary study provides.

The principle being proposed here is not, of course, that the computer should replace the professor or the book, but simply that the computer should perform the tasks that it can do most profitably and efficiently. In this capacity, the computer would function not as the professor’s replacement or rival but as a kind of teaching fellow, directing the basic but essential learning processes that are relegated to the machine.

OBJECTIONS TO THE USE OF COMPUTERS IN THE LIBERAL ARTS

The computer can help to revitalize the liberal arts only to the extent that the professoriate welcomes its technology. Although faculty in increasing numbers are making use of the computer, the reservations of many colleagues—especially in the liberal arts—are still strong and need to be addressed.

Recent studies show that faculty have in fact “discovered” the computer. According to a survey conducted in November 1985 by the American Council of Learned Societies, 45% of all faculty respondents either owned a computer or had access to one for their exclusive use; in 1980, by contrast, the figure was 2%. This increasing use foreshadows broader educational application, according to a study prepared by the Corporation for Public Broadcasting: Faculty Perspectives on the Role of Information Technology in Academic Instruction reports that professors view the instructional potential of the computer favorably to the extent that they have used the technology. With respect to specific applications, 83% of the respondents stated that the computer could help develop such generic thinking skills as problem-solving, analysis, and writing; 80% stated that the computer could encourage students to be more active learners; and 79% stated that the computer could help students learn important concepts or skills that are difficult to master.

Nevertheless, among faculty who do not use the computer—especially in the disciplines of the liberal arts—there is still a widespread conviction that the computer is inimical to their enterprise. “Nothing that is human,” said Terence, “is alien to me;” by a strange corollary, some professors believe that nothing cybernetic is congenial.

Mind Control

For some, the notion of a computer as guide to the thinking process is threatening, conjuring up visions of Orwellian mind control. These faculty fear that if students look to the computer as a mentor, as a guide to thinking, and as a source for answers, the students’ own thinking processes will come to resemble the mechanism of the computer: lock-step, single-minded, relentless. Such professors fear, as did Karl Marx, “the intellectual desolation, artificially produced by converting immature human beings into mere machines.”

Easy Answers

Other proponents of the liberal arts, less alarmed that the computer will dehumanize the user, nevertheless fear that students may become satisfied with the clear-cut formulas and authoritative answers of the computer and thus fail to look beyond the terminal screen for answers. These professors fear a technological perversion of Occam’s Razor—the philosophical principle that, given two competing interpretations of a phenomenon, the observer should choose the simpler. They are concerned, in other words, that students who use the computer will be content with the simplified, accessible, pre-determined patterns it provides and stop their quest for richer, more complex answers and solutions.

Abrogation of Thinking

Underlying both of these views is the concern that an unthinking reliance upon the computer could lead an individual to abrogate his or her mental powers. But both views overestimate the likelihood that the computer can thus undermine one of the most cherished goals of the liberal arts. Critics of computers in education frequently lack experience in using computer-based lessons and misunderstand how a computer works. Ironically, they exaggerate the power and attraction of the computer, and they underestimate the inevitable and salutary resistance that characterizes the response of most users to computer-based lessons.

However credulous the students and however circumspect the developers, postsecondary users of computer-based lessons are likely to discover that some of their choices and responses have not been anticipated. Their inevitable reaction of frustration, even to an otherwise effective program, will prevent them from becoming mesmerized and indoctrinated. In other words, the user’s experience of the computer both engages and alienates. Ideally, of course, it does the former more consistently than the latter. But even the alienation can be useful in signalling the existence of alternative responses and approaches. This tendency of the computer simultaneously to engage and detach is a characteristic often overlooked by the most adamant of inexperienced critics.

Limitations of Algorithms

There are, however, other proponents of the liberal arts—not only familiar with the computer, but knowledgeable about its programming—who object to the computer on the basis of a more deeply rooted educational and philosophical principle. The opposition of these faculty colleagues is directed not to
the computer as an instrument, but to the algorithm as a problem-solving device. Their views call for a more thorough examination.

An algorithm is a rule or process for solving a certain type of problem, as in basic arithmetic when we use an algorithm to find the lowest common denominator of a series of fractions. But, the use of algorithms outside the realm of mathematics and the natural sciences troubles many humanists. Can there be an algorithm for writing an expository essay? For reading critically in an academic discipline? The computer scientist, accustomed to solving a wide range of problems by means of algorithms, may answer these questions with a qualified "yes." The humanist, however, is likely to answer the same questions with a resounding "no."

Algorithms and Ambiguities

For humanists, an algorithm is of questionable worth in their disciplines because the mitigating circumstances surrounding any important human activity render rigid formulas nugatory. Humanists have studied the human condition—across the continents and throughout the ages—and they have developed a respect for the complexities and ambiguities of life. Morality, values, the deepest truths that individuals need to stabilize their psyches and enrich their experiences all are inimical to generalization. In fact, the humanities engender a tolerance for ambiguity, a wariness of simplistic formulas, final solutions, incontrovertible truths.

And so, to these critics, the computer is unwelcome as a teaching fellow, not so much because it is a technological instrument but because it proposes to solve problems in a heretical manner with tidy formulas, with algorithms. They know the computer must run its programs and solve its problems by following a single path, however rapidly and relentlessly; it does not take kindly to serendipity. By contrast, the human brain, which follows a mysterious multi-path route in solving problems, can use intuition as well as logic; its wonderful vagaries cannot be simulated by machine.

Algorithms as Simplifications

In one respect, these opponents of computers are correct: algorithms in the liberal arts are oversimplifications. And, if our primary concern in the teaching of thinking skills is only the delineation of the richness and complexity of these skills, we would have to forsake algorithms and therefore computer-based instruction. Algorithms would utterly fail to capture the mystery of the thinking processes, the wonders of inspiration, what Wordsworth calls "a leading from above, a something given." However, our initial concern in the teaching of thinking skills is not to analyze and account for these skills, it is to impart them to undisciplined, maturing minds. For this purpose, the oversimplification of algorithms is not only conducive to learning, it is necessary. Later, of course, after students have developed the rudiments of thinking skills, the professor will have to supplement the algorithms and present the rest of the story.

Algorithms and the Teaching of Writing

The successful use of algorithms to develop thinking skills is perhaps best exemplified by recent strategies in the teaching of writing. In fact, this discipline can be considered a paradigm because the process of composition is taught at so many educational levels, is undeniably a complex thinking skill, is squarely within the domain of the liberal arts, and is congenial to the use of computer-assisted instruction.

When adolescents begin to learn composition, most of them have trouble organizing their ideas. Consequently, their writing teachers have sometimes taught organization by means of the algorithm of the five-paragraph theme. According to the formula, the first paragraph introduces the subject and presents the thesis, and the fifth paragraph restates the thesis and concludes the essay; within this frame, the body of the paper presents three separate illustrations of the thesis in one paragraph apiece. This elementary organizational strategy calls for thinking skills, and the majority of students are not likely to learn to organize their essays without rigid adherence to the formula. The prudent teacher therefore will not overemphasize the fact that the five-paragraph theme is useful only for papers that call for illustration as a pattern of organization and for topics that can be developed in three examples. In other words, the limited abilities and pressing needs of the students warrant the teaching of a simplified organizational formula, an algorithm.

Eventually though, the teacher of writing in college must present techniques better suited to the developing thinking skills and broader needs of the students. The old algorithm must be superseded and a new one employed. Widely taught now is a pattern derived from the study of professional writers that is tailored to the needs of students. This much heralded writing process consists of the four separate stages of: (1) pre-writing (i.e., considering audience and purpose), (2) incubating ideas, (3) composing drafts, and (4) revising the essay. Naturally, presenting this new algorithm requires dismantling the old one, and college freshmen are sometimes disillusioned to discover they can no longer rely on the handy framework of the five-paragraph theme.

Is the new algorithm of the writing process universally applicable? No. A sportswriter with a midnight deadline has scant time for incubating ideas; an executive responding to a memo may have few options for selecting a format. But, for the students in English 101 and for the writing they will be called upon to do, the algorithm of the writing process is valid, in being rooted in the actual composing process of professionals, and is educationally sound, in imposing useful and relevant guidelines suitable to the developing student. For these reasons, the prudent professor will not overstate the fact that this process can sometimes be set aside when the author's purpose or audience warrants.

To summarize the point of this lengthy example, we can concede that a central thinking process cannot be reduced to a formula; at the same time, we can maintain that at various stages of a student's education, algorithms can be useful in developing simplified and productive patterns of thinking. Such algorithms must be based upon the thinking processes of trained, mature minds; and these algorithms will have to be
expanded or exploded later by the professor, even at the cost of some disorientation or disillusionment to the student.

**Algorithms as Models of Thinking**

Once we grant the educational value of algorithms in the liberal arts, we can begin to develop algorithms that model the problem-solving processes of various disciplines and then use those algorithms as the basis of computer-based lessons. Already available are excellent computer-based lessons in pre-writing that engage students in Socratic dialogues about the salient features of the papers they are about to write (for example, the purpose, audience, length, thesis, supporting points, and likely audience response). By extension, the process of critical reading and the other thinking skills necessary for a revitalized curriculum in the liberal arts can also be distilled into useful algorithms that are rooted in the practice of experts and suited to the needs and abilities of college students.

With the computer as the students’ teaching fellow, the role of the professor in the liberal arts will be to focus on the more complex, more important processes that the computer cannot address: to stay mindful of the limitations of algorithms, the complexities of life, and the value of a tolerance for ambiguity. Anticipating the students’ restlessness over the computer-based lessons, the professor can use class time wisely by exploring answers that the computer did not anticipate. Thus, the professorial role is not merely to supplement or complement the computer-based lesson on thinking skills; it is also to elevate the lesson to a higher conceptual plane.

**Teacher as Director**

How the professor remains in control of the educational process of teaching thinking skills can be explained by a metaphor from the world of the theatre. The director of a play confronts the rich ambiguities of a dramatic text, extracts a coherent pattern of meaning, and imposes upon the theatrical production his or her conception of the work: the range of characterizations, the patterns of blocking, the tone of dramatic moments. Then the performers, having assimilated the unified and coherent conception of the show, draw upon their own talents and creativity to make natural, to fulfill, even at times to adjust the director’s original conception. And they do so at the behest of the director.

In much the same way, the professor may confront the rich complexity of a thinking skill, devise patterns or algorithms to make the skill comprehensible to the students, and impose these patterns rigorously and authoritatively with the help of the computer. The student, having assimilated the thinking process imposed by the computer, must then be encouraged to discover the limitations of the imposed process and adjust the learned algorithm to deal with unique features of the problem-solving situation. Only through the combination of steps will the professor impart to the students what the Association of American Colleges calls “some sense of the wonders, complexities, ambiguities, and uncertainties that accompany the experience of learning and growing.”

**PROSPECTS FOR COURSEWARE ON THINKING SKILLS**

Even if the professoriate was of one mind in welcoming the computer as a friend of the liberal arts, using the computer in developing thinking skills would, at present, remain in potential. Nevertheless, three recent trends give promise that the potential can be realized in the foreseeable future.

**Improved Commercial Software**

One reason for optimism is the improvement in commercial software and in teachers’ skills in using the programs effectively. Educators are now successfully using sophisticated commercial programs at various academic levels and in various disciplines by subordinating the programs to the larger goals of the courses. A promising development at the elementary level is the Higher Order Thinking Skills project, which is currently in its third year and funded by the Department of Education at several sites across the country. Participating students use several commercially available instructional games that call for the same thinking skill (e.g., estimation); then they link the strategies discovered in the computer lab to concepts presented in their regular classrooms (e.g., estimation in arithmetic); finally, the students reinforce their synthesis of skills by programming questions and answers into a computer lesson with the format of a quiz show. According to Stanley Pogrow, the project director, students in the experimental group improved in thinking ability to a greater extent than did the control groups.

**Methods of Learning and Teaching**

A second development hastening the use of the computer to teach thinking skills is also more pedagogical than technical: the heightened awareness of the way students learn and professors employ the unique thinking skills of their disciplines. In its report on the college curriculum, the Association of American Colleges finds a basis for improvement in our imparting of such skills:

A new area of research, still in its infancy, has been evolving during the last decade... It is directed toward understanding how students learn (or fail to learn) specific subject matter, and what difficulties they have with various modes of abstract logical reasoning, what preconceptions or misconceptions impede their mastery of concepts or principles in the given subject, what instructional approaches and devices are effective in helping learners overcome the obstacles which are encountered, what exercises and feedback accelerate the development of various desirable skills, and how best to make use of the new instructional technology. (p. 16)

The report emphasizes the fact that the new research is not limited to the field of psychology but extends to “research indigenous to specific subject areas—research having results that can be readily understood and directly applied by teachers of the subject.” These investigations of the ways students learn, together with explorations of instructional ap-
proaches, may ensure that the capabilities of the computer receive careful attention.

In conjunction with the studies of how students learn is a new engagement by subject-matter experts in analysis of their disciplines. Liberal arts faculty are making explicit the steps of what they do when they employ the unique thinking skills of their various fields. Such scrutiny promises to issue in courses that emphasize the processes of analytical thought and therefore leave the students with more than notebooks of test-worthy details.

**Authoring Systems**

The third reason to anticipate the use of the computer for teaching thinking skills is a technological one: the development of sophisticated authoring systems. Until recently, the creation of exemplary computer-based lessons required the content expert to collaborate with a programmer and an instructional designer because the faculty member seldom possessed enough of the three skills to work successfully alone. Invariably though, the faculty member ranked lowest in the triumvirate. In the early years of courseware development, the programmer generally prevailed because he or she was most knowledgeable about the computer’s capabilities. More recently, the instructional designer has generally been accorded the final word in the shaping of the lesson.

Now however, authoring systems based upon principles of instructional design and offering “programmerless programming” have lessened the need for involvement by designers and programmers. So to the extent that the professor understands the disciplinary thinking process and to the extent that the lesson will be based upon an algorithm of that process, the professor can direct the form of a computer-based lesson in an authoritative way.

In summary, three developments—improvements in the quality and implementation of commercial courseware, increased understanding of how students learn and how faculty teach disciplinary thinking skills, and the advent of sophisticated systems for authoring—all suggest that in the near future professors can make the computer a teaching fellow to help students acquire the thinking skills of their disciplines. However, if this potential is to be realized, the professoriate of the liberal arts will have to keep abreast of technological developments and the pedagogical opportunities they provide. If faculty fail to take responsibility for innovative educational applications of the computer or if commercial developers do not rely upon educators for insights into the central thinking processes, then courseware to develop thinking skills is not likely to emerge, and an important educational potential of the computer will fail to materialize.

**REFERENCES**
