DOCUMENT RESUME

ED 052 516 EM 009 076

TITLE	Technological Augmentation of Human Cognition: An Interdisciplinary Review.
INSTITUTION	Smithsonian Institution, Washington, D.C.
SPONS AGENCY	Office of Naval Research, Washington, D.C. Personnel and Training Research Programs Office.
PUB DATE	15 Jun 71
NOTE	43p.; Prepared by the Interdisciplinary Communications Program Staff
EDRS PRICE	EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS	Artificial Intelligence, Cognitive Processes, *Computer Assisted Instruction, *Computers, *Conference Reports, Educational Development, Educational Technology, Electromechanical Aids, *Instructional Design, Instructional Innovation, *Interdisciplinary Approach

ABSTRACT

A series of five interdisciplinary conferences held over a two-year period explored new teaching and training concepts and methodologies which offer powerful, symbiotic means of augmenting human cognition. The basic discussion points of the conferences are summarized. It was felt that the conferences were significant in that they brought together participants with diverse backgrounds and focused on a substantive concept--Technological Augmentation of Cognition (TAC). A TAC system was defined as a system capable: of extending and complementing the human mind's natural learning skills; of making each student more aware of his own learning skills; and of making each student more aware of his own learning processes than is presently possible and so motivating him to improve these processes. Twelve major TAC problems were identified, and design requirements for a TAC system were established which emphasized the need for planning and cooperation among the many TAC projects now extant. Conferees warned against the "trivial use" of computers, that is, use which does not exploit the computer's full capabilities. Two action programs were completed which consisted of a popular monograph and a proposal for a TAC museum exhibition. A list of conference participants is appended. (JY)

TECHNOLOGICAL AUGMENTATION

OF

HUMAN COGNITION

An Interdisciplinary Review

Staff
Interdisciplinary Communications Program
Smithsonian Institution

June 15, 1971

This research was sponsored by the Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research, under Contract No. N00014-67-A-0399-0004, Contract Authority Identification Number, NR No. 154-288/12-11-68 (458).

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
Interdisciplinary Communications Program
The Smithsonian Institution
Washington, D.C.

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
Technological Augmentation of Human Cognition: An Interdisciplinary Review

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Technical Report

5. AUTHOR(S) *(First name, middle initial, last name)*
Staff, ICP

6. REPORT DATE
15 June 1971

7a. TOTAL NO. OF PAGES
46

7b. NO. OF REFS

8a. CONTRACT OR GRANT NO.
N00014-67-A-0399-0004

b. PROJECT NO.
NR 154-288

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT
Approved for public release and sale, distribution unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Personnel and Training Research Programs, Office of Naval Research
Arlington, Virginia 22217

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INTRODUCTION

THE GROWING SET of crises on the domestic scene is rapidly emerging as the primary priority item on the agenda of those responsible for the structure of American society.

The continual focus on the problems of today is not surprising. Man, since the beginning of his early evolution, has been primarily an "ad hoc" problem-solving creature. We can easily imagine the survival of small gatherings of our ancestors, depending upon their ability to recognize the demands of the environment and to shrewdly circumvent its immediate threats.

Through recorded history, though we see man changing his life style, his personal and social values, though we see him erecting civilizations and then watching them crumble, he has remained the same. Problem-solving is his survival kit. Today the problems are different, to be sure, both in their greater complexity and in their elusive subtlety. Only man's problem-solving ability must be developed to a comparable state of complexity and subtlety. Pollution, crime, hunger, urban chaos, over population, depletion of natural resources, racial tension, inefficiency and intransigence of complex social and political systems, and, finally, widespread identity diffusion -- these are the crisis problems threatening man's survival today, and they must be dealt with.

While these crisis problems can be seen in their unfolding complexity and critical urgency, two situations have developed which militate against a united ability to achieve solution: 1) THE POPULATION EXPLOSION has created a situation in which, even though there is more educational activity than ever before, there is more illiteracy in the world than at any other point in verbal history, and 2) THE KNOWLEDGE EXPLOSION, in which the total body of what there is to know doubles in a decade or less, has created a situation where the literate population is more ignorant -- in comparison to all there is to know -- than at any other period in history. The gaps created by these situations are explosive in themselves, domestically and internationally.

If we were to try to establish a single phase of our lives central to all these problems, we would be hard pressed to find one that is more pertinent than education. It is, or at least it should be the phase of each man's life that is most responsible for the development of his problem-solving capabilities. Education has traditionally occupied a prominent position in American society. However, it has begun to reap as many criticisms as compliments of late, perhaps because many see the dire necessity of closing the gap between what education does today and what we know to be necessary.

It is said that modern education is impersonal, cold, and dehumanizing. However, an educational system could be focused on and be controlled by the individual, be responsive to his own rates of learning, be flexible enough to respect and require his own individual responses.

It is said that modern education is years of boring memory work which stifles the seeds of creativity in children. It could contain dynamic learning displays, programmed to respond to demands of the learner for different perceptual presentations of a given subject matter, of geometric structure which could be revolved, about which questions could be asked and answered -- questions which arise from the natural curiousity of the individual.

It is said that modern education is irrelevant to the needs of society. Imagine an educational system that can be used by the impoverished and the well-to-do alike, and one that can achieve remarkably rapid results in either case; an educational system that can teach rote memory items more swiftly and so leave precious time for education in the general principles of life -- giving actual experience in modeling and identifying cause and effect, crisis and cure. A system could do all this and simultaneously monitor itself, collect the data for guidelines to accomplish its own improvement, and adjust the specific programs of the individuals using it.

Imagine a system that is truly perception expanding -- one that enables man to telescope time so that he can experience far greater amounts of pertinent reality and command far greater resources of matter for immediate mental manipulation than ever before. Abstraction-promoting features of a possible new educational system could very well be the most significant (and necessary) social mutation that man could engineer to accomplish his further evolution.

Although there are many who would like to have the present education system destroyed in order that a better one could take its place, education, like most institutions, is subject to inexorable and continuous change and evolution. Urgency, the persistence of change, and a developed and sophisticated technology provide our society with the potential for a remarkable reformation and expansion: The reformation and expansion of our educational system is envisioned above.

Over a period of two years, a diverse group of professional men and women met in interaction groups that were convened to examine alternative approaches to education and the means to precipitate action. One common bound provided the parameter within which they worked: The central role that education plays in the majority of urgent crises and the potential of technological augmentation of human intellectual performance for alleviating those crises.

PROJECT HISTORY AND METHODOLOGY

A WORK/STUDY CONFERENCE held 18-20 November 1970 successfully concluded a series of five interdisciplinary interaction-discussion conferences that were designed to explore new teaching and training concepts and methodologies, particuarly since new technologies provide a potentially powerful, symbiotic means of augmenting human cognition.

The conference series began over two years ago when the Director of the Personnel and Training Research Programs of the Office of Naval Research, in consultation with professionals in the field of technology and education, felt that further exploration in the field was imperative. It was also felt that such exploration should seek to determine two issues: 1) research programs upon which to establish bases for innovation and improvement, and 2) critical analyses of current and projected concepts and techniques. Because the educational technology field is very rapidly developing, it seemed advantageous to adopt a methodology that would be multidisciplinary in nature and could benefit from interdisciplinary interaction.

Thus, the Personnel and Training Research Programs of the ONR funded a proposal of the Interdisciplinary Communications Program (ICP) for a series of conferences to accomplish the two broad goals mentioned. The ICP, an office that is on the private side of The Smithsonian Institution and is located in Washington, D.C., specializes in organizing interaction-discussion conferences.

ICP conferences reduce the communication barrier that normally exists among scientists and other professionals of various disciplines as they find out that they have a mutual interest in the solution of common problems.

The first of the series of interdisciplinary workshops on Computers and Educational Technology was held 18-19 March 1969 at the Belmont Conference Center in Elkridge, Maryland. Serving as an initial planning session for the newly-formed Smithsonian Committee on the Technological Augmentation of Cognition (TAC), the March meeting (i) established the general strategy and logistics of the Committee, (ii) provided a preliminary discussion of the problem areas of the field, and (iii) resulted in the delineation of several action programs designed to encourage the needed basic research in the field.

The Second Belmont Conference of the Smithsonian Committee on TAC was held 9-11 November 1969. The discussion at this meeting included a review of three ongoing research systems pertinent to computer augmentation of learning, a discussion of the need for a greater understanding of human intellectual processes and a model of those processes, the need for more sophisticated interfacing systems, and the need for construction of a futuristic prototype of a TAC system. Action programs that had been proposed at the first meeting were also reevaluated on the basis of their feasibility as well as for the purpose of assigning priorities. The highest priority was assigned to the composition of a popular level monograph to communicate the Committee's conception of what TAC systems have to offer for the future.

The Third Belmont Conference of the Smithsonian Committee on TAC was held 15-17 March 1970. An in-depth discussion of the aims, mechanics, style, outline and publishing options, audience and distribution of the proposed monograph comprised the major part of the allotted time. Distinctions were made between short-term and long-term Committee goals. Developmental aspects of the monograph concepts and the projected field-oriented impact of its view of CAI were also discussed. Two action programs, the founding of an "Intelligence Institute" and the proposal for a large-scale experiment, were evaluated.

The Fourth Belmont Conference of the Smithsonian Committee on TAC was held 14-16 June 1970. Discussion at this meeting centered around (i) prototyping of a special exhibition at the Smithsonian which would exemplify the ingredients of a TAC system, plus educate and inform people generally about the past and present development of computers in education; (ii) outlining the basic concepts and contents of a popular monograph on TAC-based ways to use computers in education (plus a re-evaluation and codification of the TAC III discussions relating to the monograph); (iii) discussing the fundamental changes in educational practices brought about by TAC systems' ability to efficiently utilize a more relevant theory of concept formation;

and (iv) reviewing and evaluating past TAC committee activites. It was decided that Drs. Papert and Merzbach would actively continue the development of both the monograph and the exhibition design along the lines suggested by TAC group discussion during the conference. It was further recommended that a final TAC work/study conference be held to thoroughly review and revise these documents so that they might be readied for implementation.

The Fifth Belmont Conference of the Smithsonian Committee on TAC was held 18-20 November 1970. This meeting was called for the express purpose of thoroughly reviewing and revising the popular monograph being developed by Dr. Papert and the exhibition plan being developed by Dr. Merzbach. Most of the conference was given over to word-by-word and line-by-line constructive criticism of the documents. However, consensus was achieved on many important conceptual bases for the two projects.

A list of the twenty (20) individuals who participated in one or more TAC meetings is shown in Appendix A. The interdisciplinary interaction-discussion approach proved an effective method in pursuing the goals of the project, and proved a modern adage concerning education: "Specialized knowledge, the characteristic tool of modern man, is internal, personal, in a way that no property right can be internal .... The man who brings such an asset into cooperation with the specialized skills of other men deals from a strong position and will increasingly protect. . .his self-respect and self-expression."

The sections which follow in this report summarize the basic discussion points of the conference series.

SIGNIFICANCE OF THE STUDY

THE SIGNIFICANCE OF THIS PROJECT lies in the professional interaction of the participants, each bringing specialized and generalized information and experience, focussed on a substantive concept -- technologically augmenting human cognition. The five interaction meetings brought together the pieces of a larger matrix of concepts and information assembled and intellectually massaged over a two year time-frame. While there were two specific, visible outputs -- a monograph describing a substantively new method of teaching with computers and a complex design for an exhibition on computers in education -- an important "by-product" was also generated and will continue to be important over the years: A network of professionals, known to one another personally as well as vicariously, will continue to share ideas and research results leading to more effective uses of their skills, energies and resources. These endeavors will provide important vehicles to gain widespread appeal, understanding, and support for the power and effectiveness of user-oriented, man/machine interfaces in the field of learning; additionally, these endeavors should provide impetus for decision-makers to further experimentation and implementation in technologically augmenting cognition and, equally important, should provide impetus at the grass roots to use creativity on designing programs on readily available equipment. One additional important outcome was the graphic effectiveness of the interdisciplinary interaction discussion format as a means of grappling with complex issues and searching for subtle and sometimes fundamental conceptual developments for dealing with old problems in new ways.

TOWARD A NEW DEFINITION

IT BECAME APPARENT TO CONFEREES quite early that before any meaningful discussion could occur a definition of the scope of the group's activities need be the first order priority.

The initial attempt at delimiting the field of computer augmented cognition came from Dr. Bryan who compared it to a daisy. He said, "If you labeled the center of the daisy as computer augmented cognition it is possible to conceive of the petals of the daisy overlapping the center of it and overlapping each other in some sense." He listed for the eight petals of the daisy: artificial intelligence, natural language processing, psycho-linguistics, learning theory, instructional theory, speech recognition, synthetic speech, and mathematical modeling of the aforementioned.

At other times, as the discussion focused momentarily on problems of scope, other participants fell in either of two camps. One camp was represented by those participants who encouraged the broadest possible statement of scope of the field and the action of the Workshop on the field. The other camp consisted of participants who favored a more narrow statement of goals. For example, Dr. Atkinson stated, "I don't see this committee being primarily concerned about computer simulation or artificial intelligence. It's looking at a different hunk of the pie although that work is of direct relevance. . .I think the area of artificial intelligence and of computer simulation. . .

is not a focus of this committee. I think they are important activities, but this committee somehow is really looking at the problem of computers augmenting mental processes, and the instructional side of that certainly has to be a big side of it."

Dr. Bryan summarized his position by saying, "It would seem to me that it would be unwise to choose too narrow a limit, and quite unnecessary. Some of the more interesting problems, once attacked, may prove to be far more effectively used in, let's say, games and simulations, than they would be in some sort of a tutorial interaction or Camelot smorgasbord."

Dr. Bryan continued: "So I would urge, personally, that the scope be broad enough to cover the kinds of things that were on my mind when I used the term 'computer augmented cognition.' On the other hand, I wouldn't be terribly interested in trying to mount studies to find out whether kids ought to have different colored pencil boxes, or whether the ETTV ought to have high towers or low towers. I would like to keep it in the computer related domain, because it seems to me that's the big exciting, expansive area. This is not to deny the very thoughtful and intelligent things that you have said to this end. We do not want to put things on computer just because we have computers and do things in a hard way when they can be done effectively in a simple way."

A further analysis of the various statements which were made on this topic area seem to indicate the possibility that the inhabitants of either camp held their position due to the focus of their own work in the field. Those whose focus was research on the technological side of computer assisted instruction preferred the narrower statements of scope while those whose work in the field focused on the psychological aspect of technological instruction preferred the broader statement of goals.

After reviewing the needs of the field and the present state of the art, participants indicated that it was desirable to change two conventional concepts. They wished to avoid the use of such established terms as "education" and "learning." They wished to avoid being "locked in" by the old concepts. They wanted to communicate the need for entirely innovative concepts of education and CAI. Thus, they developed the concept of a "technological augmentation of cognition" (TAC), as a sophisticated, advanced, and promising development that is distinct from conventional CAI.

Some descriptions of the TAC system were voiced frequently enough to convey the general picture of what the conferees had in mind. Terms such as "user-oriented," "user-controlled," and phrases such as "capable of dynamic manipulation of graphics" or "capable of operating in both iconic and symbolic modes" were often used. The conferees agreed that the most desirable level of computer-presented courses enabled the student to learn the subject matter by allowing him to manipulate it in a way heretofore impossible. The burden of the branching should be left primarily in the hands of the student. The mere verbatim transference of the textbook to a computer was decried. The nature of the software and the interfacing of a TAC system was described as capable of expanding the perception of the individual student. It would collapse the natural time and distance between cause and effect to enhance the student's ability to perceive and understand correlations. It would free the student from limitations of availability of data or materials, and even from some of the limitations of his own nature. By presenting the material in a flexible manner, guided by his own curiosity, it would render material more interesting and relevant.

The TAC system was described as belonging as much in the home as in the school. Adult learning could be greatly enhanced by TAC systems through home consoles that would set both the young and the old free from artificial and rigid limitations of time and boundary of learning. Remedial learning could be improved since the TAC system could be adapted to the shortcomings in each person, differences in various speeds of learning, or differences in the optimal learning environments between students. The TAC system would have prosthetic potential in allowing for patient repetitive teaching of the handicapped. The TAC system was described as capable of extending and complementing the human mind's natural learning skills, making each student and adult much more aware of his own learning process than is presently possible, and so motivating him to improve these processes. The extent to which this concept was currently applied in research projects would determine whether that project was perpetuating a "trivial" use of the computer. Dr. Glaser pointed out, however, that "what is trivial for the computer is not necessarily trivial for education. It is a major advance in education."

NEEDS OF THE FIELD

WHILE IT IS EASY to become enamored with conceptual designs of systems which "might be," truly fruitful conceptual designs occur after thoughtful discussion of "what is" -- creativity and pragmatism each thrive when juxtaposed in this way. Conference participants were able to present a clear picture of the current shortcomings in CAI research. Such discussion was considered essential to ensure the success of any attempt to plan basic research to counteract these shortcomings. Some of the major needs that were discussed follow:

(1) the need for a better conceptual understanding of human learning processes;

(2) the need for clear-cut criteria for evaluation of the field;

(3) the need for leadership in the field;

(4) the need for the study of the influence of human environment on computer assisted instruction, and the projected social impact on CAI;

(5) the need for development of a more elaborate, flexible, humanistic, user-responsive interface between operator and computer;

(6) the need for development of a core memory capable of retaining, erasing, manipulating, and retrieving far greater numbers of information bits than is presently the case;

(7) the need for a long-range, total-systems plan of options;

(8) the need for cooperation between research groups espousing short-term _versus_ long-term research and innovation goals;

(9) the need for greater cooperation between groups concentrating on development and marketing (the educational technology industry), and those primarily concerned with basic research since basic researchers often fear that premature development of poorly-tested, non-imaginative, primitive devices will bring into question the feasibility of the entire approach;

(10) the need for more efficient and creative utilization of present capabilities (i.e., the need for emphasis on non-trivial uses of the computer in education);

(11) the need for communicating the potential of TAC systems to administrators, faculty, and parents who are connected with existing educational institutions who are not aware of this alternative, or who, being aware, are victims of common prejudices and misapprehensions about the use of the computer in teaching;

(12) the need for greater emphasis on the inter-disciplinary aspects of the relationships of TAC hardware, software, and operational phases to promote the balanced and simultaneous development of all three.

Analysis of these 12 problems revealed that while many professionals in the field concentrate primarily on hardware (5 and 6), the majority of the crucial problems are in the areas of software (1, 2, and 4), an interdisciplinary mixture of hardware, software, and operational approaches (5, 10, and 12), or purely operational problems (3, 7, 8, and 9) to which far too little attention is currently paid. There was general consensus on the need of research into human intellectual processes (1). It was agreed that recent work in the field of artificial intelligence might provide needed insights into this problem area. Some needs (2, 3, 7, 8, and 11) arise from a lack of operational leadership. The multiplicity of special interests that operate in the field of CAI (8 and 9) greatly complicates the emergence of a recognized leadership.

REQUIREMENTS FOR IMPROVING TECHNOLOGY AND SOFTWARE

WITH THE NEEDS OF THE FIELD in the background, and the goal of TAC systems in the foreground, the Smithsonian Committee on the Technological Augmentation of Cognition next tried to describe the conditions that are required to conduct adequate basic research for hastening the design of the desired teaching environments. Some of these requirements follow:

(1) the requirement for an increase in the number of talented human resources, (One conferee mentioned the need for young men of the caliber now entering careers in molecular biology, chemistry, or theoretical and experimental physics.)

(2) the requirement for operational systems of more truly "humane" dimensions and user control, designed to optimize social interaction,

(3) the requirement for funding only quality work in fewer numbers of research centers so as to avoid the current diffuse funding of redundant and small-scale programs that are incapable of launching a sufficiently sophisticated effort to significantly advance the field,

(4) the pros and cons of a requirement for greater compatibility or standardization of computer languages and the documentation of programs for intercommunication and fertilization between the centers mentioned in (3),

(5) the requirement for a more stable (long-term commitment), more concentrated, and better-informed funding,

(6) the requirement of a more precise and detailed identification of the technical problems that must be solved before a TAC system can be established and operated,

(7) the requirement of a large number of subjects for testing of prototype systems,

(8) the requirement of a "metric," mutually recognized by the community of different disciplines engaged in TAC research, and capable of measuring or comparing different alternative teaching systems, or of deciding between subsystem options,

(9) the requirement of increased emphasis on creative software innovation which is the most currently neglected aspect of TAC systems.

The lack of quality work in the field (3) was described as due to the proliferation of unconnected programs that conduct parallel work on a small scale basis. To satisfy the immediate academic needs of their institutions and to operate despite financial constraints they must conduct trivial programs. The hardware and operational costs characteristic of even large CAI installations (much less the projected TAC systems) are so large that much of the time and effort available is required merely to support the system.

Funding of the computer augmented cognition field was characterized as unstable, and in a decline (5). The decline of funds as well as the dispersion of funds over too many programs has resulted in a slowdown in the rate of overall innovation. This slowdown has resulted in the drying up of funds from the primary contractors of the past. The lower funding level has also resulted in the need to supplement research programs with trivial support work that further limits the use of time, equipment, and personnel for advancement in the field. The result is a downward funding spiral, oscillating out of control and limiting the contribution that the CAI field could make to solving some of our current crises.

The need for a more precise and detailed identification of the technical problems that require solution (6) was linked to a number of other requirements. For example, a list of such needed requirements would allow smaller institutions to concentrate on a specific item on the list, thereby not wasting their resources on projects requiring large hardware commitment but still contributing to the overall progress of the field. Further, the lack of such a list of needed engineering tasks allows certain special interests in the field to spread the illusion that all that is needed is the rapid development of extensive systems. Such a detailed list would add a much-needed dimension of critical thinking and would expose some research enterprises as being essentially irrelevant exercises. Such a list could be sub-categorized in terms of short-term and long-term goals, thereby easing the tension and promoting cooperation between basic research groups that espouse one or the other of these objectives. Finally, the availability of such a list might ease some funding difficulties since those groups requiring long-term research commitment would then have a concrete argument for long-term financial commitment. The definition of precise and realizable goals might reverse the feeling of some basic researchers and funding agencies that CAI is currently not producing sufficient results.

The establishment of a "metric" (8) is a difficult and fundamental task for all areas of social science. The hard sciences have advanced almost coincidently with the development of new and more precise systems of measurement for the comparison and testing of natural phenomena. In the field of CAI the development of a "metric" was observed to be quite relative; relative to the level of CAI on which one focuses; relative to the levels of computer-human interaction attempted; and relative to the model of the human intellectual process upon which the metric or the experiment was based.

The need for software development was especially stressed during the various meetings. The advances in hardware development, often based on the unambiguous laws of physics and the established techniques of engineering, have far outstripped progress in the field of software. This has created sophisticated machines which have but poorly utilized their potential, or the potential of the learner. Two concepts that several members emphasized were the need for greater instrumentation of software innovation and the development of more systems that would allow full user-control.

ANOTHER LOOK AT THE PROBLEM

ONE CONCEPT, grappled with and discussed time and again, is the basis of a better understanding for generating more power from the equipment, personnel, and resources currently available. Anyone in a staff or line function, exercising control over implementing programs in training or other learning activities with the use of technological aids, would do well to apply the "trivia test" to competing programs.

Conferees spent a great deal of time wrestling with the exact semantic meaning of the "trivial use" of computers. Consensus is that one could describe a trivial use of the computer as a use which does not utilize the full capabilities of the computer in augmenting cognition -- an uncreative, unimaginative use, unresponsive to student manipulation, with a very rigid, and/or previously set response pattern. Obviously, the computer when used in a trivial manner could be useful as a memorization aid or as a memorization drill, but it would not be used as a perception-expander or as a motivator of student learning. It was the general consensus that the most desirable use of the computer would be non-trivial uses, although trivial utilization was seen as legitimate and necessary for administrative functions and for a more rapid accomplishment of the necessary steps of drill and memorization, thus allowing more time for the creative aspects of the education process.

Dr. Glaser more fully described trivial by fleshing out non-trivial uses:

"...what I mean by a non-trivial use has to do with the way in which the individual using the computer can manipulate the display. There's a great degree of power in manipulating the display. I think it's this ability to really get into the heart of the subject matter and be able to manipulate the subject matter so that the person operating the computer can change these stimulus displays discovering new things in the course of learning. This is a powerful use of the computer. It's very much related to the reinforcing effects of stimulus change, and it takes a lot of work on the part of the computer programmer (in) driving the display and making decisions about generating the next display....Many times the driving of static displays is a rather trivial use of the computer."

Dr. Glaser continued to provide some specific examples of what he meant by non-trivial use of computers. "I think, even more powerful...is this ability to manipulate the elements of the subject matter, and that's still sort of artful. It's the kind of thing that happens when you can manipulate the parameters of a straight line in the Licklider program, and I think that provides a degree of stimulus change which is highly motivating to individual learners, and motivating in the same sense that all the work on exploratory motivation and stimulus change is involved.

Although the trivial use of computers is useful for administrative, drill, and feedback activities, the really exciting potentials for augmenting human intellectual processes resides in the computer's ability to expand the perception and awareness of the individual, speeding and enhancing his learning of the conventional,and enabling him to learn by experience what to date has been impossible to experience.

ACTION PROGRAMS

CONCERN FOR GETTING SOMETHING DONE in the CAI field, impetus for the concern stemming from experience, and the collective review of the needs and shortcomings of the field led the group to discuss relevant action programs. Only two of the following action ideas were concluded during the life of this project. However, the program ideas can be used and implemented by others attempting to provide better education through use of technology. A brief review of these action programs follows:

1. Communication By Monograph: While it was felt that there were so many pronouncements rampant in the field and that another publication would have little impact, it was decided that this approach had demonstrated a profitable effect in some isolated instances and could be utilized. A monograph was finally written by Dr. Papert, working independently, and it is a solid contribution to the literature on "non-trivial" uses of computers in education. From the onset the monograph was described in the following ways: (i) a popular, widely distributed look into the future, (ii) "a work that catches some of the excitement that the computer will be a major part of education," (iii) a means of revealing that the computer would be the primary cause of the needed "major overhauls in the educational system," (iv) an influence in molding the opinions of mass culture and creating a climate of change, and (v) a potential guide for research efforts that could act as a fulcrum for decision-making in educational funding.

2. Critical Mass Centers: From the very first meeting the Committee introduced an action program calling for establishment of national centers-of-excellence for TAC systems basic research. These would be a direct response to the problems mentioned earlier in this report. Such centers would be extensions of already developed systems, designed to reach a critical mass of equipment and personnel who would be free to innovate in the field. Such centers were envisioned to require a funding level of approximately $1 million a year. Except for strongly urging their creation, the group was powerless to produce action on this program outside of general discussion of what such centers would look like.

3. Communication By Exposition: One major influence on the public at large and professionals in the field would be to create an exposition which would display, in operational form, TAC-like systems. The Smithsonian Institution was seen as the best place for the inclusion of such an exhibit. During a series of conferences the exposition was discussed and later Dr. Merzbach, working independently and with her own resources, produced an exposition design. Briefly, consensus regarding the computers-in-education exhibition was as follows:

> ...there ought to be a mini-computer CPU in the $10,000 range that is completely self-contained, stand alone; second, four terminals with a key set, visual display capability of

at least a point generating capability level, alpha numerical b points; third, that the software for the mini system would at least include sampling of a variety of languages that have different functions than just processing to numerical calculation, to problem-solving, to logic analysis. Whether it had full languages or samples of those languages, it would have the illustrative educational function of what these different things represented, so that a person could appreciate the importance of different kinds of languages and what they can do. Fourth, it would lead toward an automated self-contained exhibit that would not require constant attendants. Fifth, it would have to be in the general price range, as far as the basic hardware package of $25-30,000 when exported.

...(in addition) other things would be desirable, given that to hang onto -- audio-video tape recorder playback for a visual presentation, integrated in concert with whatever might be going on in the exhibit; physically moving devices that are computer-controlled and manipulated, like a jig or a little steam shovel or something that would show how this could be done and could be programmable in a simple way by the person working at the terminal; going on possibly to even the turtle type of exhibit where there would be a demonstration of the self-programming, recursive type of evolution of a turtle going through a maze or a walk of some kind and improving each time he goes.

It was also agreed that (i) the exhibit core equipment should be modular in design (like Tinker Toys) so that it could be expanded quite readily in many unusual and exciting ways; (ii) the mini-computer should be designed (or have the capability) to interface with any other system; (iii) the cost of design, programming, and debugging should be in the $100,000 range.

Conclusion of the detailed planning work for the exposition places a body of substantive materials in the hands of anyone wishing to implement the entire exhibition or any portion of it (see supplemental report).

CONCLUSION

PERHAPS THE GREATEST SINGLE BARRIER to making massive increases in the capability of computers to truly augment cognition is that "this field, if you measure it in terms of dollars or number of people or amount of energy that goes into it, is very heavily given over to what you might call engineering -- amateur engineering at that. . . ." The basic research needs are several, including a more thorough knowledge and understanding of the learning process itself. One participant said that when you get past the amateur engineers, the next barrier to watch out for are the self-interested entrepreneurs. In any case, all barriers mentioned have one common element: They depend upon sophisticated intellectual processes to clear the obstacle and it seems clear that a great deal more brain power must be exercised prior to designing mental super chargers with computers. One conclusion seems strong, disregarding additional funding sources: If current activities were better coordinated there is a great deal that is possible in the immediate future; however, only a discrete number of systems would be possible. Certainly, one important change which must occur is the creation of a much larger operational leadership in the field; a leadership dedicated to "non-trivial" uses of computers in experimentation and operation.

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