Infrastructure for a New Discipline of Educational Computing

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Infrastructure for a New Discipline of Educational Computing

Final Report to
The Claude Worthington Benedum Foundation

Preston K. Covey, Director
Center for Design of Educational Computing
December 5, 1989

Covering the Period from July 1, 1985 to June 30, 1989

Submitted to the

The Claude Worthington Benedum Foundation
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For the Development of an Infrastructure for
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Infrastructure for a New Discipline of Educational Computing

Final Report to
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Executive Summary

This final report covers the entire program of the Benedum grant over four CMU fiscal years, from July 1, 1985 through June 30, 1989. The original grant was for the period July, 1985 through December, 1987, which period was extended through June, 1989.

I. The Overview describes CDEC's mission since 1985, in three related activities: 1. Research, 2. Development, and 3. Outreach. The purpose of the Benedum grant was to develop an infrastructure that would bring discipline and leadership to the emerging arena of educational computing.


III. The Financial Summary reports Benedum funding for the four-year period, organized by Carnegie Mellon fiscal years. The financial report therefore includes the periods covered by our prior three interim reports. Our reports to date now include:

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IV. The Appendix to this report contains a list of CDEC publications and the following exhibits on four of the ten major Benedum-supported projects:

- **The cT Programming Language:** Campus announcement of cT commercial version 1.1
- **The CMU Proof Tutor:** Brochure illustrating the 1988 version of our tutor environment for formal logic, now integrated with our full-semester computer-managed logic course.
- **A Right to Die? Videodisc:** The report submitted to the 1989 EDUCOM/NCRIPtal Higher Education Software Awards Program (in which we won the Best Humanities Software Award for 1989).
- **Art or Forgery? Videodisc:** Article from *Leonardo* (Vol. 22, No. 2, 1989) on the videodisc that discusses the impact of new technology on the disciplines of art history and aesthetics.
I. Overview

An Infrastructure for Leadership in Educational Computing

The purpose of the Benedum grant was to allow Carnegie Mellon to develop the infrastructure needed to bring discipline and leadership to the growing area of educational computing. As computer technology advances at a rapid rate and its promise for improving education both tantalizes and confounds us, it becomes imperative that dedicated centers be created to track and tame the technology, centers of knowledge for realizing the promise and avoiding the pitfalls of advancing technology, development centers for implementing the most promising applications of the technology for education.

The advance of technology is too complex and problematic to be well governed or fully exploited by teachers, faculty, or administrators in their spare time. Interdisciplinary centers of excellence, with fully dedicated staff and faculty, are required to develop the knowledge, tools, and leadership required to chart a fruitful course for educational technology.

Our nation, region, and even our campus, which is heavily invested in computer technology, needs a center that can sustain leadership in the educational applications computing -- an infrastructure that brings together the expertise of many relevant fields, that can organize the knowledge required, and apply that knowledge successfully to the improvement of learning.

The Center for Design of Educational Computing (CDEC) has attained a prominent position of leadership -- on campus, regionally, nationally, and even internationally. The most fundamental and singular achievement of the Benedum grant was to allow us to build and stabilize CDEC itself, an infrastructure within a leading university for exploring and exploiting technology for education.

CDEC is an interdisciplinary organization, whose members have national reputations in fields covering a wide spectrum of the arts and sciences. Staff members combine research, teaching, and technical expertise as well as practical experience in the design, development, and deployment of educational computing applications. Their research interests include disciplinary methodologies, pedagogy, curriculum design, interface and instructional design, programming tool design, cognitive science, learning theory, and technology management (strategic planning, ethical and social impact issues). Many CDEC research staff hold joint appointments or teach in academic departments of the university.

The development of sophisticated and useful educational software requires research and a professional infrastructure to sustain that research: research on learning processes as well as new learning tools; research on the problems of software design, development, and deployment; research on the fields of knowledge and skills whose learning the technology is designed to improve; evaluation research; research on the technology itself, its evolution and its future. But the research must be translated into development, software products that will in fact be used to improve learning. And leadership in research and development in turn requires outreach to the community of scholars and to the communities affected by the technology.
CDEC's Mission

After four years of evolution with Benedum support, the Center for Design of Educational Computing (CDEC) is now a nationally renowned research, development and resource center. CDEC's mission is to provide leadership in the design and development of advanced computer applications for education. CDEC carries out this mission through three types of activity: (1) research on technology, learning processes, and the design of effective computer-based learning environments; (2) development of productivity tools and exemplary applications for computer-based learning; (3) outreach and dissemination to faculty, students, and other educational institutions.

1. Research

CDEC research focuses on design issues, learning processes, and the impact and strategic management of educational technology.

Design issues are central to the development of educational applications of computing in any field. Research interests of CDEC staff include design principles for authoring and programming tools; principles of effective human and computer tutoring; the design of dynamic, interactive displays; the use of dynamic, visual representations of abstract concepts; the use of color in computer displays; qualitative reasoning in quantitative domains; and the reasoning and problem-solving processes that computer activities are designed to facilitate.

The future of educational computing raises a different class of planning and design problem, important to human enterprise and technology management. CDEC's research activities encompass issues of campus planning, ethics in the development, use and deployment of information technologies, and social impacts of educational technology. CDEC's director also serves as director of Carnegie Mellon's Center for the Advancement of Applied Ethics (CAAE). The CAAE participates in several collaborative research and educational projects on ethical issues in the development and management of computer and information technologies.

CDEC's contributions to research on learning and educational technology are documented in the list of CDEC publications and reports contained in the Appendix.

2. Development

CDEC's success and leadership is most obvious in its development of national award-winning applications of technology. I highlight the award winners here. In section II, Development Projects, I report in more detail on the ten major Benedum-supported projects.

CDEC software has won at least one award (twice it has won two awards) in each of the three years since the EDUCOM/NCRIPTAL Higher Education Software Awards Program has been established. We are the only university and center with this distinction. This is the only national software awards program for higher education. It is co-sponsored by EDUCOM, the national computing consortium for universities and colleges, and the National Center for Research to Improve Postsecondary Teaching and Learning (NCRIPTAL) at the University of Michigan.
Award-winning CDEC software includes:

The Great American History Machine:

EDUCOM/NCRIPATAL Distinguished Software Award, 1987.


Graphs and Tracks I & II:


A Right to Die? The Case of Dax Cowart - A Videodisc for Ethics:

The Nebraska Videodisc Design/Production Group Merit Award, 1988. 
(The Nebraska program is an industry-wide competition, the videodisc industry’s ‘Oscars.’)

EDUCOM/NCRIPATAL Best Humanities Software Award, 1989.

Ruth Chabay, CDEC Senior Research Scientist, won the 1988 EDUCOM/NCRIPATAL Best Tutorial Award for her General Chemistry software, developed with Stanley Smith.

CDEC will submit the CMU Proof Tutor (below, Section II) to the 1990 EDUCOM/NCRIPATAL Awards Program.

CDEC’s applications are more than tools for aiding learning in the classroom; each tool or application embodies a theory, a philosophy, a wisdom about how teaching, learning, and research can be improved through appropriate uses of technology. CDEC’s development projects embody general and useful lessons for education beyond the particular subject matter they help teach.

Tracking the development of advanced microcomputers, workstations, and distributed computing technology, CDEC cannot address every educational need or every opportunity presented by the technology. We have to be selective in our efforts. We have focused on the development of tools and applications that promise to be both strategic and seminal.

A strategic application is one that addressess pandemic educational problems or crucial bottlenecks, promotes intellectual skills not well promoted by traditional means, effects improvements in the learning process with the computer that cannot be accomplished without the computer, and forces us carefully, critically and creatively to rethink, reaffirm or revise our basic concepts, pedagogy and goals.

A seminal application is one that will propogate use, impact, and benefits in more than one domain or discipline, serve as a paradigm for propogating needed innovation in educational strategy or curriculum, and exploit or advance important disciplinary or educational research.

Section II highlights the strategic and seminal impact of CDEC's Benedum-supported projects.
3. Outreach

The experience and wisdom that CDEC gains from its own research and development activities allows CDEC to serve as a resource center for the campus and other institutions. CDEC has been consulted by developers and strategic planners from regional institutions, internationally reknown universities (for example, MIT, Oxford University) and many universities abroad (for example, in Australia, New Zealand, Japan, Hong Kong, England, Germany, France, Spain, Italy, Sweden, the Netherlands, Switzerland, and Mexico).

On campus, CDEC has provided developer support and educational opportunities for both faculty and students. CDEC staff are available to consult with faculty on all stages of the planning, design, and implementation of large and small educational software projects. To further the academic use of computing, the development of university curricula has become a responsibility and point of leadership for CDEC as a result of the quality and academic status of its staff. CDEC took responsibility for developing and managing the Computing Skills Workshop (CSW), a university core course in 'computer literacy' required of all in-coming undergraduates. CSW is the major component of a broader initiative -- the Computer Languages, Applications and Systems Program (CLASP) -- through which CDEC has sponsored other for-credit computing courses that fall outside the mandates of academic departments.

Regionally, CDEC has provided technical support to all the workshops and conferences of Benedum's Consortium for Computing in Undergraduate Education, cT summer workshops for high school teachers, and collaboration with high school teachers through the Allegheny Intermediate Unit (CDEC's award-winning Sketch program was developed in collaboration with regional high schools, as is our current work in introductory physics.) CDEC staff consult on development projects with regional institutions such as the Carnegie, Buhl Science Center, and St. Francis Medical Center. CDEC is headquarters for the Interactive Learning Forum, a regional consortium of corporate, government and academic organizations involved in applications of laser optical technology which sponsors several workshops each year.

Nationally, CDEC helps support and coordinate the efforts of other academic communities to exploit modern computer technology for education through hands-on training workshops, national conferences, and leadership in national consortia. CDEC has been headquarters for the Interuniversity Consortium for Educational Computing (ICEC), for which it provides technical support and has organized several national workshops on cT. CDEC is headquarters for the McDonnell Foundation Program in Cognitive Studies for Educational Practice, which supports research projects and postdoctoral fellowships. This program sponsored a national conference on Computer Assisted Instruction and Intelligent Tutoring Systems: Shared Issues and Contemporary Approaches. Jill Larkin and Ruth Chabay are co-editors of the conference papers (Lawrence Erlbaum, 1989). CDEC is headquarters for the American Philosophical Association's Committee on Computer Use in Philosophy, which Preston Covey chairs, and publishes Computers & Philosophy, an interdisciplinary journal. In August 1989, CDEC hosted the Fourth International Computers & Philosophy Conference. CDEC is a charter member of the Research Consortium of the Smithsonian Institution's National Demonstration Laboratory for Interactive Educational Technologies (NDL), which facilitates technology transfer and collaboration among educational institutions exploiting laser optical technology. As a leader in multimedia technology, CDEC organized a session at the 1989 Society for Active Learning through Technology (SALT) conference on MultiMedia in Higher Education; Robert Cavalier is editing the volume of conference papers. With the Smithsonian's NDL, CDEC is organizing a session for the 1990 International ADCIS Conference on the use and impact of multimedia technology internationally.
II. Development Projects

Benedum support has been targeted on our ten most strategic and seminal development projects. CDEC development efforts are focused in three areas in which we aim to excel: programming tools that enhance the productivity of faculty and student developers; model applications that exemplify the best that can be achieved with modern computer technology (in particular, intelligent tutors and simulations); and multimedia environments that enrich learning by combining media (computer graphics, text, full color motion video, and audio) -- in effect, by combining the powerful visual impact of film or television with the interactive powers of the computer.

1. Productivity Tools

CDEC aims to put better means of production in the hands of faculty and students. Two major achievements have been a Common Lisp for the Andrew system and student workstations and the cT programming environment, which is portable across diverse operating systems and computers.

Common Lisp for the Andrew system and workstations.

CDEC ported a fully functional Common Lisp and artificial intelligence (AI) development tools (eg., OPS5) to Carnegie Mellon's Andrew system and Unix workstations. Both public domain Kyoto Common Lisp (KCL) and the enhanced and commercially supported Ibuki Common Lisp (IBCL) have been made available to support AI applications and courses on our advanced-function workstations. KCL/IBCL were chosen because of reasonably sized core images, in order to run under four megabytes (the typical memory on workstations commonly available to students). Functionally equivalent or superior Common Lisp environments require twice or more the memory as KCL/IBCL. Further specifications on the technical environment are found in:

Covey, P. & A. Sobel. The Andrew/Kyoto Common Lisp Project. CDEC Technical Report # 87-05.

Sobel, A. Andrew/Kyoto Common Lisp. CDEC Technical Report # 87-06.

Among the important applications exploiting the Common Lisp are the CMU Proof Tutor and the VALID on-line logic course. The latter is a complete semester's course totally managed by the computer, from which students can access the assistance of the Proof Tutor.

In addition, several undergraduate and graduate courses -- in philosophy, psychology, social science, mathematics and computer science -- use the Common Lisp environments, from introductory computing to a course in Interactive Fiction.
The cT programming environment.

CDEC's premier (now commercial) product for distribution is the cT programming language and environment for the Macintosh and IBM PC/PS2 series computers. (A copy of Macintosh version 1.0 was included with our August 1988 report.) The cT package is now published (in version 1.1) by Falcon Software and widely distributed around the nation and the world.

CT was designed to address three major obstacles associated with conventional programming languages that inhibit faculty (or student) developers of educational software:

1. Difficulties or inefficiencies in learning and use.
2. Lack of support for modern graphical interfaces.
3. Lack of portability or compatibility across hardware and operating systems.

Unlike conventional authoring languages, cT is a flexible general-purpose programming language.

One singular achievement of cT is portability: the language and its applications run without change on popular (IBM PS/2's and Macintosh) microcomputers as well as Unix workstations. (CDEC itself is distributing the Unix versions of cT.)

Another crucial advantage of cT is its dynamic on-line help system. This allows scrolling, cross-indexed documentation to be searched and read in its own window on the screen. Sample code illustrating cT functions can be clipped from the help window, pasted in the source code window and then run in the execution window. The programmer can alter either the code or its executed displays to see and experiment with different programming functions and their effects. Incremental compiling and a dynamic graphics editor allow very rapid learning, design and prototyping cycles.

In sum, CT offers the following unusual strengths for modern computing environments:

* incremental compiling
* interactive graphics in windowed environments
* instant portability across diverse computers
* automatic rescaling of text and graphics
* multi-font text
* menus (which operate appropriate to the computer, in pop-up or pull-down mode)
* mouse and keyboard inputs
* analysis of words and sentences
* analysis of numbers and algebraic expressions
* rich sequencing options
* standard calculational capabilities
* numeric and text files
* on-line reference manual with executable examples
* accurate and informative error diagnostics
* full color support (new in version 1.1)

CDEC will further enhance cT as an environment for developing interactive video control programs and interfaces (cf. Multi-Media Environments, below).
An important application of cT is to develop sophisticated modern interfaces for educational or research software built in other languages like Lisp or C. Links to Fortran will be built as well. For example, this allows faculty to build AI engines in Lisp but construct user interfaces more readily in cT, as has been done with the CMU Proof Tutor (below), or to capitalize on powerful research programs for student use by building user-friendly instructional interfaces.

CT has also been used to construct sophisticated applications de novo -- like Sketch, an intelligent tutor for 'sketching' algebraic equations that won a 1987 EDUCOM/NCRIP7AL Distinguished Software Award, and PD World, an environment for simulating all varieties of n-person iterated Prisoner-Dilemma-type models of the evolution of cooperative behavior.

CT has been adopted by myriad faculty across the spectrum of the liberal arts, at Carnegie Mellon and other schools, for all these purposes and has become a cornerstone of Carnegie Melion's long-term strategy for facilitating wider development of educational applications by faculty.

CT has also been used by students for the development of original educational software. Three stellar examples actually developed for use in undergraduate courses are Chemistry Lab by David Thompson, Genetics Lab by Pam Reinagle, and Nuclear Power Plant Simulator by Stuart Shapiro. Shapiro's project was in fact saved from fatal implementation difficulties in the C programming language by the decision to design and implement in cT. (All three of these students were CDEC Scholars supported by the CDEC Scholarship Program in Educational Computing - CSPEC, one of our major campus outreach activities.)

CDEC offers faculty and high school teacher workshops in cT as well as for-credit courses for Carnegie Mellon staff and students. Workshops have also been given at Carnegie Mellon, Vassar College and Cal State, Northridge for members of the InterUniversity Consortium for Educational Computing.

The story of cT, historically and technically, and its exemplary applications is of interest in its own right. Besides the cT book and manual, the following papers and publications chronicle the development and strategic impact of cT:


Covey, Preston K., Joseph Devine, Stephen Fienberg and Christine Neuwirth. The Integration of Educational Computing in the College of Humanities & Social Sciences. CDEC Technical Report # 88-17.

Lewis, Clayton and Gary M. Olson. Can Principles of Cognition Lower the Barriers to Programming? Boulder CO: workshop paper, 1986. (Available from Lewis, University of Michigan, Ann Arbor or Olson, University of Colorado, Boulder.)


Scheftic, Carol, David Trowbridge and Jill Larkin. Sketch: A Tutor for Graphing Algebraic Equations. CDEC Technical Report # 87-03. Final application to the EDUCOM / NCRPTAL Higher Education Software Awards Program, May 1987. (Sketch, built in cT, received a "Distinguished Software" award in the 1987 competition.)


Sherwood, Bruce A. CMU Tutor. A videotape jointly produced by CDEC and IBM. CDEC Videotape # 87-17, October, 1987.


Trowbridge, David E. Quick Generation of Lecture Demonstrations and Student Exercises.
2. Model Applications

Besides good productivity tools, the field of educational computing needs good model applications that exemplify the best that can be achieved with modern computers, that illustrate what it means to be strategic and seminal in the use of advanced computer technology.

Our applications attempt to research and advance the evolution of certain strategically important types of application: sophisticated simulation, graphics and data-analysis environments and so-called 'intelligent' computer-assisted instruction (ICAI) and tutoring systems (ITS). Carnegie Mellon has distinctive strengths in cognitive and computer science across the arts and sciences; it is natural then for CDEC to embody and exploit the application of cognitive science, learning theory, artificial intelligence and expert system research to education.

Special emphasis is placed on design research and modern interface design. There are generic design and implementation lessons to be learned from our work that will propagate research, design and development strategies beyond the shelf-life of any particular application. These lessons and our research agendas are reflected in the publications listed in the Appendix.

The intelligent tutoring and simulation applications supported by Benedum are described below. These projects are strategic in the educational problems they address and seminal in the design and learning research which they have propagated (at other universities as well as Carnegie Mellon).

PD World

A perfect example of an application that is both strategic and seminal is PD World, a simulation environment (built in cT) for generating and testing Prisoner-Dilemma-type models of the evolution of cooperative behavior.

PD World is strategic because it addresses an analytical approach that is hard to teach in general educational settings but that is crucial to the understanding of important work in several disciplines. It puts serious research tools in the hands of students as only the computer can: the environment is extensible, allowing a student to either replicate or extend all extant research (such as is reported in Robert Axelrod's seminal book, The Evolution of Cooperative Behavior).
PD World is seminal because it invites and propagates use across a spectrum of disciplines: philosophy, political science, decision science, economics, social psychology, policy analysis, and socio-biology at Carnegie Mellon and many other universities. The program has become integral to courses in the Humanities & Social Sciences College, the Graduate School for Industrial Administration, the School for Public & Urban Affairs because the program facilitates hands-on understanding of a major intellectual and practical problem integral to social institutions and interpersonal affairs: the evolution of cooperative behavior among self-interested agents.

ANALYTICS

The ANALYTICS package for the IBM PC gives students practice in skills basic to formal logic and the analysis of arguments. It consists of three programs: Symbol, Truth, and Argue. Symbol generates drill exercises in symbolizing English sentences, and Truth in evaluating their truth value. Argue checks proofs and furnishes an environment for reconstructing arguments given in natural language into valid deductive form.

Symbol provides randomly generated exercises in symbolizing English sentences in a formal language for sentential logic. There are two basic types of exercise. In the first, the student is given a schematic English sentence, e.g., "P if and only if either Q or R." The student must identify the overall form of this sentence -- whether it is a conjunction, a disjunction, a conditional, or a biconditional -- and then symbolize the schema. The program will recognize the correct answer as well as a variety of basic errors and provide appropriate feedback in each instance. In the second type of exercise, the student is given actual English sentences and assignments of their atomic components to sentential letters. The problems are randomly generated based on a library of atomic sentences, which can be edited at the instructor's discretion. The user has options allowing control over which kinds of logical connectives are used in the problems and how complex the problems will be.

Truth provides randomly generated exercises in the truth-functional analysis of schematic English sentences. Each exercise begins with the presentation of a schematic sentence and the truth value of its components, e.g., "Either P or Q, if and only if R, where P is true, Q is true, R is false." Based upon the valuations given, the student must then determine whether the entire schematic sentence is true or false. Before making a determination, the student can see how the sentence would be symbolized, review the truth tables for the connectives, or build a truth tree for the given problem. If the student makes an incorrect determination, she is led step by step through a truth tree analysis to the correct truth value. As with the Symbol program, the user has options which allow control over which kinds of logical connectives are used in the problems and how complex the problems will be.

Argue both checks proofs and provides an environment for reconstructing English arguments in valid deductive form. In either mode, the student can work through problems stored in files or create problems of his or her own. When using the program as a proof checker, the student works problems which consist of a conclusion and premises from which to derive that conclusion. The student moves towards the conclusion one step at a time, using any of the rules in the deduction system. The proof checker will catch any errors as they are made. If the student is working a problem from a stored problem set, he or she can view any stored hints that the instructor has provided. There is no limit to the number of hints which can be provided with a problem. Argument reconstruction problems consist of an actual English argument and assignments for translating the argument into a language for first-order predicate logic. The
student must translate the argument into the formal language, providing any missing premises. The instructor can use stored hints to provide guidance on formulating missing premises. The student then uses the proof checker to prove the reconstructed argument valid by deriving the conclusion. At any time in the program, the student can view English translations, generated by the program, of every line in the proof.

Besides their use in Carnegie Mellon courses, CDEC has provided non-exclusive use of the programs to Virginia Klenk (West Virginia University) for her textbook Understanding Symbolic Logic (Prentice Hall) and Waveland Press (for Gustason and Ulrich’s Elementary Symbolic Logic); both these popular textbooks lacked their own accompanying software.

For further information on the design and educational impact of these programs:


Covey, Preston, "Logic and Liberal Learning: Some Salient Issues", in Formal Logic and the Liberal Arts, a special double issue of Teaching Philosophy 4 (3/5) July/October 1981.

Covey, Preston, "Formal Logic and Philosophic Analysis", in Formal Logic and the Liberal Arts, a special double issue of Teaching Philosophy 4 (3/5) July/October 1981.


CSYM: A Symbolization Tutor for First-Order Predicate Logic.

This tutor is functionally similar to but much more sophisticated than the SYMBOL program in the ANALYTICS package (above) because it can generate both symbolization problems and advice and because it does so for first-order predicate logic. During the summer of 1989 a visiting computer scientist and philosopher from the University of Barcelona, Spain, began work on a Spanish version of CSYM. See:


The CMU Proof Tutor.

This sophisticated environment provides much more power than the ARGUE program in the ANALYTICS package (above): it is an artificially intelligent tutor (built in Common Lisp) with a sophisticated graphics interface (built in cT) for constructing natural deduction proofs in first-order logic developed for the Andrew workstation. The Proof Tutor is used in our on-line computer-managed logic course (the VALID program, made possible by the Common Lisp port to Andrew, described above) and as an aid in any course requiring the use of first-order logic. The Proof Tutor represents the state of the art in intelligent logic tutors. The Appendix contains an illustrated brochure describing the recent version. See also:


The Proof Tutor is another example of a seminal CDEC project because it has generated collaborative research by a linguistics graduate student at the University of Pittsburgh and post doctoral fellows in psychology on the learning and problem-solving strategies which the tutor is meant to facilitate.

Graphs & Tracks I & II: Kinematics Tutor & Simulation.

CDEC Research Scientist David Trowbridge developed this kinematics tutor and simulation environment, which won two awards in the 1988 EDUCOM / NCRPTAL Higher Education Software Program: "Best Physics Software" and "Best Integrated Software," for the integration of student guidance with student-controlled construction. The program, written in cT for the Macintosh or advanced-function workstation and designed to teach kinematics concepts and graphing skills, supports two activities critical to introductory kinematics: "From Graphs to Motion" presents graphs of position, velocity and acceleration versus time. Students then construct tracks on which a rolling ball executes the motion represented in the graphs. Help is available that provides step-by-step guidance through the solution. Students can generate new problems by creating and storing their own graphs. "From Motion to Graphs" demonstrates the motion of the rolling ball and students must sketch the corresponding graphs. The student is given a graphing palette or may draw freehand. The program provides feedback, focusing on dubious solutions and prompting the student without directly correcting errors. See:


Sketch: Algebraic Equation Graphing Tutor.

Developed by CDEC Research Scientists Jill Larkin, Carol Scheftic and David Trowbridge, Sketch won a "Distinguished Software" award in the 1987 EDUCOM / NCRPTAL Higher Education Software Program. Sketch, written in cT for the Macintosh or advanced-function workstation and designed to develop skills in visualizing and sketching graphs of algebraic equations, teaches a systematic approach to sketching curves that emphasizes a step-by-step procedure for transforming simple expressions into more complex ones and transforming the graph accordingly, rather than the plotting of individual points. Sketch incorporates the following functions and attributes of an artificially intelligent tutor: a model for problem solving for a significant class of problems, so that its utility is not limited to stored problems; a coach for applying the problem-solving model (which can be turned off for free experimentation) that diagnoses errors and gives detailed suggestions at each step; a collection of instructive examples that is readily expandable by the teacher; a facility for entering arbitrary new problems; and an interactive guide to using the program, obviating the need for documentation. See:


3. Multimedia Environments

Multimedia environments are singled out for special emphasis and attention, even though they also naturally belong in the category of 'model applications.' Two features distinguish our multimedia projects:

One is what is distinctive about multi-media environments themselves: the combination of full color, motion video and sound along with text and high-resolution graphics in a hyper-media format. Computer-based multimedia environments combine the data-richness and motivational powers of film or television with the interactivity and navigational powers of the computer. This combination of resources and powers poses both special opportunities and especially complex design and delivery problems. Hence, the need to treat the evolution of multi-media applications as a special category.

The other distinctive feature of our multimedia projects is the initial arena of application: ethics, social issues and the arts -- domains of human values inquiry, typically neglected in the advance of educational technology to date.

No strategic vision of the evolution of educational technology can afford to ignore the promise and problems posed by developing multimedia technology (currently, interactive videodisc and CD-ROM technology, although these particular technologies are not definitive of the rapidly evolving state-of-the-art).

No strategic vision of educational computing can afford to ignore potential applications in the neglected domains of the humanities and the arts, those 'soft' areas of open-ended value-laden inquiry that seem to resist practical and rigorous methodologies delivered even by traditional means or media. Curricula and pedagogy in these domains have never been so evidently important or so arguably in need of improvement.

For these reasons, CDEC has made a strategic priority of tracking and developing the promise and problems of multimedia technology and has chosen the particularly problematic staging area of values education for doing so. In the fullness of time, we will expand our efforts into the areas of science and technology education that are already exploiting computer-based multimedia.
Too many real-world problems for which we aim to equip our students are not well captured in books, lectures, or class discussion. These media cannot always simulate the practical realities or stimulate the human sensibilities that motivate and confound political or ethical dilemmas.

Typical students lack one important commodity for learning: life experience - or enough of it. Typical academic settings lack adequate means to provide this commodity. In academic terms, the lack is one of sufficient data and context -- particularly in areas like ethics, the arts, or politics, where much of the essential data and context are perceptual, experiential, even emotional. Multimedia environments are useful for the rich data, texture, and context they allow us to import into experientially barren groves of academic study -- allied with interactive computer technology for the easy control, flexible exploration, and disciplined reflection it can induce.

Computer-based interactive video combines the power of television or film with the freedom and control of the computer: the opportunity for dramatic impact, lively interaction and careful reflection; speaking at once to our senses, our sensibilities and our minds; offering a very 'life like' learning experience.

One priority for CDEC's computer-based work is a series of projects under the aegis of Project THEORIA (tay-o-ree'-a), whose agenda is reflected in its acronym: Testing Hypotheses in Ethics/Esthetics: Exploring the roles of Observation, Rationality, Imagination, & Affect.

The goal of Project THEORIA is to design compelling, interactive simulation environments for testing hypotheses and 'theories' of the arts and morals -- among the most difficult and disputed of human value domains. Our focus is values inquiry.

Theoria (Greek for theory) is also an allusion, to the paradigm of theory rooted in concrete observation, to the etymological roots of both theory and theater in the ancient Greek verb theorein: to see, to view, to behold. Through exploitation of multi-media technology, we aim to provide a theater for ethical and esthetic theory, to bring the theory to ground in realistic settings that are rich in the complex data that any competent theory must first behold in order to explain.

In the 'Golden Age,' in the beginnings of the Western philosophical tradition in Greece, the vehicle for ethical theory was the theater: a spectacle, with universal elements of 'the human condition' reflected by chorus and convention in the concrete, compelling drama of Greek tragedy and comedy. Theory in the arts and morals most naturally begins in what we experience first-hand, in what we see, imagine, or feel. Skills of moral reflection or imagination, like the practical skills of the surgeon or the theoretic skills of the scientist, require an operating theater or laboratory for practice. We need good analogues of that theater or lab for 'hands on' inquiry in the arts and morals: an experiential crucible for learning by seeing and doing. Four projects underway reflect the wide range of value issues amenable to interactive treatment:

- **A Right to Die?** The Case of Dax Cowart (a videodisc, first in a series)
- **Art or Forgery?** The Case of Han Van Meegeren (a videodisc)
- **Birth or Abortion?** The Human Face of a Dilemma (mixed media, including videodisc)
- **Values Boggled:** Ethics, Art & Money in the Work of J. S. G. Boggs (in concept phase)

Benedum has supported our two major and most advanced videodisc projects under the auspices of CDEC's Project THEORIA:
Final Report to the Benedum Foundation

A Right to Die?  The Case of Dax Cowart - A Videodisc for Ethics

This videodisc won the 1988 University of Nebraska Videodisc Design/Production Group Merit Award and the 1989 EDUCOM/NCRPTAL Best Humanities Software Award.

The videodisc presents the famous case of Dax Cowart -- a victim of severe burns, blindness and crippling injuries who persists under treatment to insist that he be allowed to die. Through interviews with Dax and other principals in the case (his doctors, lawyer, mother etc.), the user investigates basic ethical issues regarding quality of life, autonomy and competence, the obligations of medical professionals, etc. Throughout, the user must continually address the central dilemma: whether Dax should be granted his request to die - as well as the reasons why / why not.

The videodisc will support eight or more hours of interactive exploration of the issues and case material, in two basic modes: 1. Access to video archives in which video segments are organized by both major issues and principals. 2. Socratically guided inquiry by which the user is led eventually to consider all the facts, issues and viewpoints. The program branches and questions the user in order to challenge her judgment and responses with contrary views and visuals. A NoteCard facility records the user's responses to questions or notes, organized under the relevant issue for output. The program uses these responses to direct the user to apt or challenging branches of inquiry and to query the consistency of her evolving views and judgments. When a final position is taken on whether to let Dax die, surprising consequences follow for either choice.

Dax Cowart’s request to die poses the kind of hard choice and hard case that makes or breaks our theories about what is right, best, or decent to do. Hard cases in ethics are born of rude realities, perplexing feelings & conflicted viewpoints. But those rude realities rarely invade the groves of academe & studied reflection is rarely afforded amidst the pressures of practical life. Our videodisc aims to help bridge the gap between theory and practice, thought and feeling, to stimulate and simulate crucial conditions of moral reasoning in ways that other media cannot.

Critical moral reasoning requires, inter alia: empathy, the vivid representation of the interests of others; practiced confrontation with hard facts, unforeseen consequences & strong feelings; an appeal, at once, to our senses, sensibilities & minds; with opportunity for challenge & reflection.

Ethical theory must be brought to grips with issues in 'live,' affecting contexts, rich in the complex, perplexing data that any theory must first behold in order to explain. Theory or wisdom in morals begins most naturally in 'real' experience, in what we see, imagine or feel. Skill in ethical analysis or moral judgment requires the equivalent of a laboratory, studio or theater -- like the scientist's, artist's or surgeon's -- for 'safe,' hands-on, experientially rich practice.

For all these reasons, the study of ethics needs interactive video. And the world of interactive video technology needs a 'proof of concept' project, an experimentum crucis to show that it can serve the cause of education in ethics and address salient, pressing social issues.

The crucial test is by our colleagues in law, medicine and health services; our disc is intended to be useful in settings of professional education and practice: it is presently being site tested at St. Francis Medical Center (Pittsburgh) and Dartmouth's Medical School where it will be integrated in professional programs. But prime targets are also postsecondary teachers and students, with whom it has been used and evaluated for two years. And because of the wide 'bandwidth' of the medium, its power to communicate on several levels with diverse audiences, we also see the videodisc as a resource for public schools and libraries.
As another example of the seminal nature of CDEC development projects, which seek to promote research as well as use in several domains, the videodisc has spawned two research projects at Carnegie Mellon. One is collaborative among CDEC, a visiting researcher from the University of Michigan, and our English Department: this project is evaluating the effectiveness of the videodisc with students in a rhetoric course on Argument & Controversy. We are making presentations on this research project to Herbert Simon's Cognitive Science Seminar during 1989-90. The other is a dissertation research project on the role of emotion in ethical argumentation, by a graduate student in our Rhetoric Program. Research results will continue to improve our applications.

Two other research projects have adopted the videodisc as a case study: one in the Netherlands on the pedagogy of ethics, the other on multimedia design paradigms at Columbia Teachers College.

A book chapter and several papers are in process on the videodisc. A copy of the following videotape featuring *A Right to Die?* is included with this report to Benedum:

Produced by the National Center for Research to Improve Postsecondary Teaching and Learning, the University of Michigan, Ann Arbor MI.

**Art or Forgery? The Case of Han Van Meegeren: A Videodisc for Art/Aesthetics**

This videodisc aims to do for aesthetics and art history studies what the other projects attempt to do for education in applied ethics: to put interactive computer tools and compelling, realistic data for intensive hands-on inquiry into the hands of users (be they undergraduates in aesthetics or art history courses, high school art teachers or students, or members of the museum-going public).

The videodisc raises compelling, generic issues in aesthetics, art history or 'art appreciation' in the context of a dramatic 'real life' art-world scandal that occurred at the end of WWII. It is designed for university, school, or public deployment (e.g., in libraries and museums), by teachers in class settings (for interactive presentation and discussion) or by individuals for self-study.

The videodisc program is in effect set up as a 'detective story,' putting the user in the role of an investigator who must sift through and weigh the historical, scholarly, visual, and forensic evidence to determine whether a given painting (sold to Nazi Hermann Goering during WWII by a third-rate Dutch painter, Han Van Meegeren) is in fact an authentic Vermeer (as claimed by the art experts) or a forgery (as claimed by Van Meegeren, in order to escape a life sentence as a Nazi collaborator). Aesthetic issues are also raised about the status of a good forgery as art and what makes any artful work a work of art. The program is designed to exercise the user in the critical, observational, and analytic skills required of an educated observer of visual art. The videodisc makes resources from museums and libraries around the world readily accessible.

The goals of the videodisc are to provide (1) easy access to a rich store of information and art work in one convenient place to provoke (2) close attention to details and features of art works and (3) critical analysis of the evidence pertaining to issues of attribution and aesthetic value -- in order to enhance the observational and analytic skills needed to appreciate visual art, to generate and test hypotheses under duress from contradictory data.
Issues of attribution therefore serve as heuristic vehicles for basic lessons in the interdependence of fact and value judgments, the nature of human value judgment and evidentiary standards, and the weighing and balancing of protean 'evidence' that can at once both compel and mislead in the conflict of alternative explanations.

The videodisc has been deployed in two versions with 90 students in our Aesthetics course in 1988 (IBM PC version) and 1989 (Macintosh version) and has been shown at several major conferences: in art education, philosophy, the American Association of Museums, and SALT (the major national conference on new developments in laser optical media). See:


The seminal nature of this project is illustrated in the LEONARDO article, which illustrates the impact of new teaching technology on the conception and practice of research as well as education in the disciplines of aesthetics and art history.

The project also exemplifies how technology can help us bridge the gap between the ivory-tower (universities) and the public (through deployment in museums, as described in the American Association of Museums volume, above). Brandeis University, which is field-testing the videodisc, is our demonstration site for a consortium of museums and universities in the Boston area.
III. Financial Summary

The allocation of Benedum funds is summarized on the following pages. I can provide detail breakdowns by individual staff and projects (as provided in our previous reports) if desired.

CDEC to date has received $675,000 of the $700,000 grant per the schedule reported below. We expended the total $700,000 by the end of fiscal year 1988-89 as reported below and are simply running a deficit equal (within $3) to the $25,000 balance.

Administrative staff expenditures were minimized and contained in the first two years. The lion's share of staff support costs went towards either development or outreach work by CDEC principals. Even our Administrative Assistant was involved in outreach work; she was responsible for technical and logistical support for ICEC and C-CUE conferences.

The CDEC Director's salary covered by Benedum represents not administrative work but rather the large portion of my time devoted to hands-on work on development projects as Project Director and co-principal: the logic and multimedia projects were my creations and responsibility, although I was of course assisted by programmers and other principals. The costs under each development project represent the portion of salaried time devoted to those projects by CDEC programmers and principals, staff whom CDEC was able to cultivate and retain because of these projects. The same is true for our outreach projects, where I have indicated the apportionment of salaried time devoted to campus, regional, and national outreach work, respectively.

In the first year of the grant, before CDEC had a capital equipment budget from the university, our capital costs were heaviest. This was a start-up time when basic equipment (especially workstations) was needed. After the first year, I minimized capital and operating costs in order to devote Benedum funds to development and outreach work, as our university support increased. Other projects for which Benedum provided start-up funds, like the Educational Software Library, have since been supported by the university. The CDEC Newsletter was merged with other computing newsletters into a comprehensive campus-wide publication, the Cursor.

I believe that CDEC has proved the worth of the charter we have written for ourselves, as described above under CDEC Mission. We have thereby had to prove our worth to the university and, as a result, now enjoy increased university support compared with 1985-86 when Benedum support began. We are especially grateful to Benedum for the support that allowed us to grow and become productive through these four formative years.
# Benedum Budget 1985 - 89

For Carnegie Mellon Fiscal Years (July 1 - June 30)

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* TOTAL EXPENDITURES | 224,589 | 146,098 | 273,378 | 32,476 |

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** SALARIES (breakdown by project)

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## RESEARCH & DEVELOPMENT

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## Model Applications

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## Multimedia Environments

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## OUTREACH

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### National Outreach

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IV. APPENDIX

One copy of the EDUCOM/NCRIPタル Higher Education Software Awards Program videotape *The Best of 1989* demonstrating the videodisc *A Right to Die? The Case of Dax Cowart* accompanies this report. This epitomizes the success and impact of CDEC's development agenda.

The following materials are here appended with this report:

- Campus announcement of version 1.1 of the cT programming language.
- Illustrated report on the CMU Proof Tutor.
- An article from the prominent art and technology journal *LEONARDO* on the CDEC videodisc *Art or Forgery? The Case of Han Van Meegeren*, which discusses the impact of new technology on the disciplines of art history and aesthetics.
- A paper describing the CDEC videodisc *A Right to Die? The Case of Dax Cowart*.
- A list of CDEC publications and reports.