Proof of Concept: Educational Innovation and the Challenge of Sustaining It

Volume 2

Second Annual Report -- 1992-1993

The Dalton Technology Plan

New Laboratory for Teaching and Learning
The Dalton School
1993

Contents

***

To the Dalton Community

In reviewing this past year, there are three things that stand out:

First, the Dalton Technology Plan has taken root in the school. The Faculty has taken up the opportunities to use the new technologies to meet their educational objectives in creative and compelling ways. Whether one focuses on the Science Department with astronomy, geology, and chemistry or the English Department with the study of the Bible, Russian literature, American literature, film and Shakespeare, it is clear that the School is a beehive of purposeful activity. And the key is that it is purposeful; the technology is always intended to serve the educational goals around which there is and has been a clear consensus. We seek methods and means that allow us to empower individual children to think for themselves and find in their studies a meaningful engagement with questions of personal significance.

Second, we have had success in initiating the dissemination of our discoveries and creations. Whether the medium is through the published word or collaborative projects such as those with Chula Vista, Boys Harbor or Columbia University, we have begun to see how our projects play in diverse environments. All the early indications are that they have a high degree of flexibility and can be productive of positive results in varied settings. We look forward to continuing and expanding this effort.

Third, we have achieved a national reputation as the School that has most successfully and productively incorporated the new technologies into the mainstream of a school curriculum. Acknowledged as pursuing a philosophy of responsible progressivism, we receive requests from literally hundreds of people for information or to make a visit to the school. Apple's selection of Dalton and the New Laboratory as best representing the educational landscape of the future and their decision to feature Dalton in their broadcast production, *Technology and the Evolving Classroom*, have consolidated our position as a national leader in the field.

The goal for the 1993-94 academic year is to consolidate our gains, to fine-tune and further enhance the initiatives begun over the previous two years. New enterprises will be kept to a minimum and emphasis will be placed on existing opportunities for extending the use of Dalton-produced software and bringing to fruition unrealized capacities in the cyberspace of our networked environment. There are six areas within which we will pursue our goal:

The Technical Environment - We have created one of the most complex technical environments in existence in the school world. For example, we will very shortly have in excess of 1,000 E-mail users on a system with only 150 workstations. This is unprecedented; the common understanding of electronic mail is that each person who has an account also has a computer. In addition, the software available to students at every workstation has grown in number and complexity. We have also recently reconfigured the network with a new server and new possibilities for phone-in use. Within such a rich environment, certain problems and difficulties inevitably emerge. This year we intend to work on improving the stability and utility of the existing infrastructure so that it serves the educational needs of our community even better than it does now.

Classroom Culture - We have focused intensely, for two years, on the development of software and on opening up a range of opportunities to both faculty and students for using that software. We have also begun to reflect on the impact of these new technologies on classroom culture and the new demands that its evolution makes on both adults and children in the school. As part of our consolidation and fine-tuning we will continue to inquire into the nature of the emerging new habits, expectations and possibilities.

Follow-up of Evaluations - In the second year of the program we have done an extensive in-depth evaluation of many dimensions of the projects in the Dalton Technology Plan. The process itself was of value since it required that project directors and other faculty engage external evaluators in conversations that were substantive and generative of new ideas and new possibilities. Further, the final evaluation reports have within them recommendations pertaining to the future development of our projects and it is our intention to look closely at each of the evaluations and decide on which of the many recommendations we intend to pursue.

Exploitation of Existing Resources - The network supports many software tools which have been available now for almost two years. Many of us have not yet learned to use these tools nor have we conceived of ways in which these tools can be deployed in our course work. For instance, the School owns multiple licenses to Microsoft *Excel*, a spreadsheet program, which could be purposively used in many different classroom environments. Another example is our E-mail system; it makes possible on-line conferences which could leaven and to some extent redirect the nature of conversations in the classrooms. Now is the time to reflect creatively on how to realize the potential implicit in the resources offered by the rich technological environment we have created.

Horizontal Dissemination - We have experienced significant success with a number of innovative projects that have been done by individual faculty members. At this juncture, we would do well to challenge ourselves to consider whether or not these projects, so successful in the hands of certain individuals, might be internally disseminated so that they become more centrally part of the curriculum for every student.

Financial - The Dalton Technology Plan's funding has remained constant for the third year. That means that, over time, our actual resources have decreased—since the cost for personnel has increased if only as a function of the raises given each year within the School. In addition, we have expanded a number of projects that we are doing, requiring more support, technical and personal. In a nutshell, we have an expanding environment and stable resources. As a result, it will be necessary this year to make some significant decreases in expenditures, supplies, and technical additions. Neither will it be possible to support the faculty with stipends to the extent that we have in the past. However, the intention is to share whatever resources we have with faculty actually engaged in developmental endeavors involving significant additional time beyond what is demanded by classroom work.

As we look to the future the exceptional will become the commonplace. Yet we are still at the early moments of a bold new time in human history. In the age of the printing press a new order emerged and it is without question that in the next decades our world will continue to evolve in its use of the new technologies and make and discover things yet unknown. If anything is essentially human, it is change and we should consider ourselves fortunate to be alive at such a fecund time.

Frank A Moretti, Executive Director, the New Laboratory for Teaching and Learning; Associate Headmaster, The Dalton School

* * *

An Overview of the Dalton Technology Plan

When the Dalton Technology Plan was initiated in the Fall of 1991, it consisted of twelve discrete projects. Perhaps the most telling indication of the success of the past two years is the fact that the impact of the new technology has refused to remain confined to the initial project categories. Last Spring, the New Laboratory for Teaching and Learning received over thirty faculty proposals for new initiatives as the success of early efforts has spilled over into new and unanticipated areas; more surprising still are the many other initiatives that have emerged spontaneously during the opening weeks of the semester as faculty and students become increasingly aware of the potential of the new technologies at their disposal.

An anecdote serves to illustrate the point. Shakespeare's oft-quoted "what's in a name" took on new meaning when the New Lab's multimedia Macbeth software had its name changed from "*Playbill*" to "*Navigator*". As the Tenth-Grade Introduction to Drama class began to demonstrate the effectiveness of a hypermedia approach to literature, the underlying software engine began to find applications throughout the High School English curriculum, and the course-specific name no longer reflected the use of the program. This year, the *Navigator* appears with teacher-designed content-bases in Russian Fiction, Film Studies, American Literature and Introduction to Literature, not to mention in Eighth-Grade English, High School Latin and Advanced Placement Spanish classes. What had been developed as software for a specific course is rapidly becoming a core technology for literary studies, and more generally, for student and teacher navigation and creation of networked hypermedia at the Dalton School.

One of the major enhancements to the Dalton Technology Plan this year is the introduction of schoolwide electronic mail. Again, we are discovering that curricular (not to mention administrative) applications for this new communications capability are emerging at an exponential rate. But our ability to sustain these applications technically has been enhanced by their participation in a common hardware/software platform which supports a variety of uses while centralizing development and maintenance.

In our third year of the Dalton Technology Plan, we intend to sustain the trend toward expansion and diversity even as we consolidate our limited resources. Our focus will be on deployment, on maximizing our capacity to accommodate the whole range of educational needs comprehensively and flexibly. In so doing, we move towards a new, and perhaps more challenging, phase of the project—namely, gathering the data from three years of experimentation and building the permanent underpinnings for the Dalton of the twenty-first century.

Luyen Chou, Director of Operations, the New Laboratory for Teaching and Learning

***

1) Educational Goals

The Dalton Technology Plan, like The New Laboratory for Teaching and Learning, is committed to certain educational values and aims that have remained essentially unchanged since the founding of The Dalton School. We restate them at the beginning of both volumes of this Annual Report because of the quantity and complexity of the materials to be reviewed. The yardstick is placed next to the product. Volume I provides an internal perspective on the Plan, while Volume II assesses our progress from without, but the documents in both volumes can only be judged in terms of the goals to which the Plan, like the Laboratory and the School, is dedicated. These goals have been variously articulated over the years; let this statement of them stand as a conceptual synthesis suited to this occasion. The culture of understanding and skills in our networked multimedia environment is dedicated to an educational process which is:

• *Constructivist* in an environment saturated with *authentic information.* An educational process is constructivist when students, driven by a compelling question of their own, are actively doing something—solving a puzzle, making something, looking for something—and skills and knowledge are enhanced as an aspect of that engagement. Information is authentic when what students do incorporates and generates primary data and concepts rather than predigested texts and definitions.

•*Collaborative* along at least three dimensions: 1) It encourages peer-to-peer cooperation rather than competition. 2) It reconfigures the relationship between teacher and student, so that the instructor becomes a guide, a leader in an open-ended activity of learning, and the profession of teaching is liberated from routines of repetition. 3) It sustains a movement of inquiry beyond the confines of the discipline, the classroom, and the school itself, making the world's resources and expertise a part of everyday educational activity and so narrowing the gap between advanced research and the life of the school.

•*Cumulative* because information stored and processed digitally is naturally accumulated in two essential senses: 1) Each generation of students is engaged in inquiries which are continuous with those of preceding and succeeding generations. Students make use of information and commentary they have inherited, just as they pass on information and commentary they are creating—a true culture of education. 2) Each individual student will build upon whathe/she has achieved over the course of a whole educational career. The concept of the portfolio will be fully realized in an evolving, self-reflective and self-modifying trajectory of intellectual and moral activity which will someday constitute what we mean by a person's education.

The documents in this report have been organized and edited so as to make it as easy as possible to judge our activities and results against these goals. But all the important documents are reproduced and contextualized completely. The whole story is given.

***

2) The External View: Evaluation, Collaboration, Dissemination

Introduction

Proofs which are less than purely logical depend on evidence. When that evidence concerns matters human, whether in a book of criticism or a court of law, its meaning is subject to interpretation. That is why people rely, whenever possible, on the judgment of disinterested outsiders when the meaning of evidence is at issue. Educational theory and practice is a human matter which arouses intense commitment. A proof of concept in education cannot in the last analysis be held credible on the basis of testimony, however sincere and informed, of authors and developers of the concept. Volume II of this report is devoted to testimony bearing on the value of this project, but coming from beyond The New Laboratory and the Dalton School.

> *The textbook is 400 years old, it has a tremendous force behind it and people think in its terms and much that has been already created for the computer in some way is being created in its image. We're trying to explore what the new forms are that are possible within the new technologies. If you're going to do that, you can't be religious about the textbook and you can't be religious about any of the educational traditions that effectively have been with us for 400 years.*—Frank Moretti, Apple's *Imagine* Series.

As the Dalton Technology Plan has expanded, so has the process of evaluation. The Annual Report of 1991-92 contained four formal evaluations from outside specialists. This report contains thirteen, presented in Part 1 of this volume. The sheer bulk of materials may seem forbidding, but it is inconsistent with the whole idea of outside evaluation to do any less. We have organized the reports in ways that maximize accessibility, and we have excerpted representative passages from each. But the complete text and context are, in each case, given.

Part 2 of this volume deals with relationships the New Laboratory has established within a larger community, a community increasingly interested in the Dalton Technology Plan from many different vantage points. Granting agencies, foundations and think tanks, schools and professional associations, libraries, museums, corporate and legal concerns—a whole range of individuals and institutions dealing with the impact of technology on American society has contributed to our work, or will do so in the future. By the same token, we have been reaching out —to Juarez-Lincoln School in Chula Vista, California; P.S. 92 in Harlem; the New York State Association of Independent Schools; the Intern Program at Teachers College, Columbia University; the Society for the Application of Learning Technologies; NYNEX; and MIT—to share the lessons we have learned. It is no accident that the term "network" refers simultaneously to an informational technology and a social-professional structure and activity. Successful, pioneering enterprises today characteristically depend upon fluid consortia of cooperating entities, and educational enterprises are no exception.

* * *

Part I The Evaluation of Projects

1) Measurable Results: the Impact of *Archaeotype* and *Project Galileo* on Basic Skills

> ***"Seldom in educational research does one see differences the size of the ones between the Dalton Technology Plan student scores and Control student scores in these studies."*** Professor John Black, Department of Communications, Computing and Technology in Education, Teachers College, Columbia University

Introduction

For people who have devoted themselves to projects sponsored by the Dalton Technology Plan, nothing could be more gratifying than the results reported in this document. Every experienced educator can tell when a teacher, a book, an assignment, or any other educational instrument, is working. Certain unmistakable qualities of engagement permeate classrooms and classwork when real learning takes place. Every educator knows it when he/she sees it, but that judgment of experience, however well-founded, can never carry the same weight as a measurable result in a controlled study conforming to established research procedures. The qualitative evaluations of classroom process and product presented later in this volume are uniformly favorable, and they confirm the judgment of our experience this year, as they did last year. But this next report marks the first time we have had undeniable *proof* of the educational efficacy of the Dalton Technology Plan—and that efficacy is not related to specifically technological activities, or even to a particular discipline. Focusing on two of our most developed projects, Professor Black's study demonstrates that Dalton students of very different ages, working in very different subject areas, are acquiring basic cognitive skills *which are transferable to domains of inquiry they have never encountered before.*

* * *

Evaluation of the Dalton Technology Plan From a Thinking Skills Perspective:

John Black, Clifford Hill and Janet Schiff, Department of Communications, Computing and Technology in Education, Teachers College, Columbia University

Introduction

> Educators are accustomed to reforms which improve skills in specific areas. The notorious practice of "teaching to the test" in order to raise scores and present an appearance of learning takes education-as-instruction to its logical extreme. In a culture saturated with such values, reforming energy is, not surprisingly, most often invested in domain-specific enhancement. But educational researchers have long understood the ultimate futility of such undertakings. For them, it is the *transferability of basic skills* that matters for any educational innovation making a claim to real significance. Testing such skills in secondary school students with theory and data from cognitive science obviously fills the bill—presumably, none of them has taken a graduate-level psychology course.

The studies we describe in this report examine the general thinking and study skills that the students have learned in the various programs of the Dalton Technology Plan (DTP). We paid particular attention to the *Archaeotype* and *Galileo* programs because they seemed the most developed and thus most ready for an exacting evaluation. We used two basic methods of examining what thinking and study skills the students had learned: (1) we examined the work (written essays, hypermedia essays, etc.) that the students produced as part of their classwork and (2) we did experiments comparing the DTP students' performance on a task in a new area to the performance of students who had not been through a DTP program on the same task. These group comparison studies were done for the *Archaeotype* and *Galileo* programs and the results are given in Part I of this report. In Part II, we give our analyses of samples of student work done as part of several other DTP programs. We compare this work either to comparable work done in a non-DTP context or to some other meaningful criteria (e.g., the National Council of Teachers of Mathematics standards for Middle School mathematics). In addition to assessing current levels of performance, we make recommendations about how to get better performance in the future and about how to gather observations better for future evaluations.

Part I: Group Comparison Studies

Because all the DTP programs share an interpretation-construction educational philosophy, all the DTP students have experienced taking the basic observations and data of some field, examining these observations for patterns, creating explanations of these patterns, arguing for the validity of these explanations and relating all this to what others (e.g., experts in the field) have said. These pattern-recognition, analysis, explanation and argumentation skills are very valuable to be learning in school because they will be used throughout one's life in any sort of adult endeavor. We devised assessment instruments that required the DTP students to demonstrate such general thinking and study skills in areas completely new to them and compared their performance to that of control groups that had not had a DTP experience. The results were dramatic in showing the value of the *Archaeotype* and *Galileo* programs. We report these results in the following two sections.

I.1 *Archaeotype—6th Grade Social Studies*

In the *Archaeotype* program, students study ancient Greek and Roman history by using observations of simulated archaeological digs to construct interpretations of the history of these sites, while drawing upon a wide variety of background information. Students work in groups around a graphic computer simulation of an archaeological dig to "dig up" artifacts, measure them and in general make observations about them, then store these artifacts and observations in a simulated museum for the whole class to access and interpret. The teacher models how to do these analyses, then provides coaching and serves as one of many information resources for the students. The students learn about ancient history by conducting authentic archaeological investigation activities in the authentic situation of a simulated archaeological site.

In the study we conducted, the students were given a booklet describing four psychology experiments examining how people remember lists of words. The students had to examine the basic observations, report on the results of the studies, find the patterns, devise explanations and argue for those explanations. They were also given some background readings in the psychology of memory. The Dalton students who had been through the *Archaeotype* program were compared to students from the Grace Church School (who also had some data-analysis experience from going through *The Voyage of the Mimi* program from Scholastic Publishers).

Overall, the Dalton students showed a 31% better performance than the control group, as shown in the following average scores (the total possible points is 60, but only an expert in the psychology of memory could possibly get all 60 points):

Archaeotype	**25.2**
Control Group	**19.2**

31% advantage for *Archaeotype*

Even more dramatic, however, was the part of this overall score that was due to argumentation and explanation (the most important part of the overall score). Here the *Archaeotype* group showed a 73% advantage as follows (here there were 30 possible points, half of the overall score):

Archaeotype	**13.8**
Control Group	**7.8**

73% advantage for *Archaeotype*

The details of the research method we used in this study and the results are reported in the following section.

Method

Participants

The experimental group was made up of 22 sixth-grade students who had participated in the *Archaeotype* program at the Dalton School, an independent school located on the east side of Manhattan. The control group was made up of 22 sixth-grade students who attended the Grace Church School, also an independent school located on the east side of Manhattan.

Materials

Students in the two groups were given a ten-page document (the assignment booklet) divided into two parts (see Appendix A.1). The first part gave the results of four memory studies:

1. In study 1 subjects listened to 20 words spoken at the rate of one word per second and then immediately recalled them.
2. In study 2 subjects listened to the same words spoken at the rate of one word every three seconds and then immediately recalled them.
3. In study 3 subjects listened to the same words spoken at the rate of one word per second but recalled them only after performing an unrelated 30-second task.
4. In study 4 subjects listened to a different 20 words (many of which were semantically related) spoken at the rate of one word per second and then immediately recalled them.

The second part of the document provided background readings on technical concepts such as short- and long-term memory. Students were asked to use these readings to interpret the results of the four studies and to present their interpretations, along with practical recommendations for improving memory, in a written report.

Procedure

Administering the Materials and Collecting Student Reports

The study was conducted in two 2-hour sessions (for a total of 4 hours) spread over two adjacent days. On the first day, the experimenter passed out the assignment booklets (Appendix A.1); the students paired up; the experimenter read the instructions on the first page of the assignment booklet; then the experimenter ran a demonstration of the kinds of memory studies described in assignment booklets. In the demonstration the experimenter read a list of 20 words, then the students wrote down their recall of them and the experimenter conducted a short discussion of what the results were. This demonstration was done so that the students could see what the studies described in the assignment booklets were like. After the demonstration, the students proceeded to work on the assignment in groups of two. While doing the assignment the students were free to use any of the resources in the Dalton and Grace Church School buildings (computers, libraries, etc.) including asking the experimenter for clarification and information questions (the same experimenter conducted all sessions). At the end of the 2-hour period on the second day, the students handed in their reports and all the work they had done in folders. The experimenter then led a half-hour discussion of the study.

Analysis of Student Reports

We performed both quantitative and qualitative analyses of the reports produced by the students in the sessions. In the quantitative analysis we devised a scoring scheme for assigning a series of numbers to each report, while in the qualitative we examined the content of the reports for the meaning behind the numerical patterns observed.

A. Quantitative Analysis of Student Reports

We devised a rubric for evaluating three dimensions of the student reports pattern: recognition, argumentation and data representation (see Appendix A.2). Given the emphasis on data interpretation in the *Archaeotype* program, we accorded the most weight to the dimension of argumentation, as indicated by the following distribution of points:

1. pattern recognition (20 points)
2. explanation and argumentation (30 points)
3. data representation (10 points)

In principle, students could receive a total of 60 points, though we should point out that the rubric was designed to reflect what might be described as expert responses to the task. This emphasis on high standards is in keeping with the larger movement in educational reform that is often referred to as *authentic assessment.*

Pattern Recognition: Students received 1-2 points for describing each of the following intrastudy patterns:

1. In study 1 the pattern of *last words/first words/middle words* (with *middle words* highly attenuated).
2. In study 2 the pattern of *last words/first words/middle words* (with *middle words* more developed).
3. In study 3 the pattern of *first words/middle words/last words* (with *last words* highly attenuated).
4. In study 4 the pattern of *last words/words grouped in semantic categories* (with *last words* relatively attenuated).

In addition, students received 1-2 points for describing each of the following cross-study patterns that relate to number of words recalled:

5. More words were recalled in study 2 than in study 1.
6. Fewer words were recalled in study 3 than in studies 1 and 2.
7. More words were recalled in study 4 than in studies 1, 2, and 3.

In effect, the number of words recalled in the studies can be ranked in the following order:

study 4 > study 2 > study 1 > study 3

Apart from these major patterns, students received 1-6 points for noticing other significant patterns (i.e., 1-2 points up to three patterns)—for example, in studies 1 and 2 when middle words were recalled, they often formed associative pairs (e.g., *cup/water*); or in study 4 the most salient semantic categories were those involving fruit and animals as opposed to those involving furniture and transportation (i.e., words in these categories were recalled not only more frequently but earlier in the sequence); and within the various categories, certain words which function as prototypes tended to be recalled first—for example, *coat* for the category of clothing and *chair* for the category of furniture.

Explanation and Argumentation: Students were expected to draw on the background readings to develop arguments supporting hypotheses about the patterns they observed in the four studies. As a consequence, arguments that drew appropriately on the background readings were awarded 1-4 points each, whereas arguments which did not draw on the background readings were awarded 1-2 points each. Here are local arguments that could be used in interpreting major patterns in the four studies:

1. In study 1 short-term memory explains the fact that the last words are the first recalled.
2. In study 2 increase in time—and thus deeper processing in long-term memory—explains the fact that more words can be recalled (especially, the middle words that can be meaningfully associated).
3. In study 3 the intervening 30-second task is used to explain not only the fact that the last words are no longer recalled first (i.e., short-term memory is no longer operating) but fewer total words are recalled (i.e., long-term memory is diminished as well).
4. In study 4 the presence of semantically related words is used to explain the fact that not only are more words recalled but the sequence in which they are recalled (i.e., semantically related words tended to be grouped).

In addition to local argumentation, students were given credit for global argumentation (e.g., these four studies suggest that meaningful associations among individual words is the most powerful factor in word recall). They were given 1-2 points if such argumentation were presented without the background readings and 1-4 points if it were presented with the background readings.

As to the final recommendations in the report, students were given 1-4 points for grounding them in the data (e.g., ample time should be provided so that meaningful associations can be formed between the items to be remembered) and 1-4 points for grounding them in the background readings (e.g., meaningful associations should be developed so that material can be transferred from short-term to long-term memory).

> This comparison is striking: in total (the first column in Table 1 on page 16), the *Archaeotype* group scored 31% higher than the Control group (25.2 vs. 19.2 — out of a possible 60), and this difference was very statistically significant, $t(38)=2.22$, $p<.02$.

Students were also given 1-2 points whenever they displayed legitimate forms of alternative explanation for the same phenomena —for example, in study

4 the fact that *cat* tended to occur early among the recalled words could have been explained by the fact that it was among the last words presented (i.e., short-term memory) and/or the fact it serves as a prototype of the "animal" category (i.e., members of such a category, as mentioned, tend to occur before members of "furniture" or "transportation" categories.

Data Representation: Students were given credit if they used numerical and/or graphic methods to represent major patterns in the four studies. With respect to numerical methods, they received 1-2 points if they calculated the means for significant patterns, such as:

1. the total number of words recalled in each study
2. the number of *first words, middle words,* and *last words* recalled in studies 1-3
3. the number of words recalled in the semantic categories as well as the number of *last words* recalled in study 4.

Students received an additional 1-2 points if they used these means to establish significant proportions, such as:

1. the relative weighting of *first words, middle words,* and *last words* that were recalled in studies 1-3
2. the relative weighting of *last words* and associated words (i.e., those in the semantic categories) that were recalled in study 4.

As to graphic methods of representation, students were given 1-6 points for appropriate use of such methods. These methods include bar graphs and line graphs that represent the proportions of different kinds of words recalled in the four studies (Appendix C, Figs. 1 and 2). Alternatively, they could have used a flow chart as shown in Appendix C, Figure 1a, to represent the input/output relations for short-and long-term memory in these studies. With respect to study 4, they might have used tree-structures to represent membership in the major semantic categories.

B. Qualitative Analysis of the Student Reports

In the qualitative analysis, we examined the content of the student reports and collected excerpts to illustrate what the reports are like.

Results

A. <u>Results of Quantitative Analysis</u>

We present the results of the quantitative analysis in Table 1. The numbers in this table are the means for the *Archaeotype* group and the Control group. The total possible score overall was 60 points, although this represents all that could conceivably be found, not what any precollege student could attain — only a specialist in the psychology of memory would have a chance of getting all these points. Thus, the important aspect of these numbers is not their absolute value, but how the *Archaeotype* and Control groups compare. This comparison is striking: in total (the first column in Table 1), the *Archaeotype* group scored 31% higher than the Control group (25.2 vs. 19.2—out of a possible 60), and this difference was very statistically significant, $t(38)=2.22$, $p<.02$. To do this statistical analysis and the others reported later, we assigned each student the score of the report created by the group (here, each group is a pair) that they were in, then calculated a t test to see how big the difference between the means of the *Archaeotype* student scores and the Control student scores were compared to the variance of these scores within the *Archaeotype* group and within the Control group.

Table 1: Quantitative Analysis of Reports Written by Students in the *Archaeotype* Group and the Control Group

	Total	Pattern Recognition	Explanation and Argumentation	Data Representation
Archaeotype	25.2	10.6	13.8	0.8
Control	19.2	9.6	8.0	1.6

As described earlier, this overall total score breaks down into subscores for recognizing the patterns in the observations (Pattern Recognition), explaining the patterns and arguing for those explanations (Explanation and Argumentation), and converting the observations into forms that could provide insight (Data Representation). This breakdown shows that the overall *Archaeotype* superiority was almost totally caused by a 73% higher performance for the *Archaeotype* students in the important Explanation and Argumentation area (13.8 vs. 8.0— out of a possible 30 points). Statistically also, this is a highly significant difference, $t(38)=3.34$, $p<.001$. There was also a slight difference in favor of the *Archaeotype* students in the Pattern Recognition scores (10.6 vs. 9.6 — out of a possible 20), but that difference was not even close to being statistically significant so we have to discount it, $t(38)=0.76$, $p>.2$.

> Both the quantitative and the qualitative results showed an impressive ability on the part of the *Archaeotype* students to create explanations of observations and argue for the validity of those explanations using a mixture of their own terms and ideas, and the technical terminology and concepts provided by background readings in a research literature.

The Data Representation scores held two surprises for us. The first surprise is that they were so low (16% and 8% of the possible, compared to 27%-53% of the possible in the other areas): neither the *Archaeotype* students nor the Control students used means, proportions, graphics nor diagrams in their discussions—they merely talked about one condition described in the experimental materials being greater than another. The second surprise is that the Control students scored better than the *Archaeotype* students (1.6 vs. 0.8—out of a possible 10) to a significant degree, $t(38)=1.95$, $p<.05$. However, the Control advantage was totally due to these students putting the observations into a database program on the computers (part of *Microsoft Works*, which they were accustomed to using) and calculating means. For example, one pair of students in the Control group displayed the database shown in Appendix C, Figure 5. This use of databases was a potentially valuable move, but the Control students did not exploit this analysis for Pattern Recognition and Explanation and Argumentation. The *Archaeotype* students did not show comparable use of database or spreadsheet programs and thus scored lower on Data Representation. Taken together, these results show that the students both need to have experience using computer programs for manipulating data, but they also need practice using them meaningfully as part of their work in analyzing authentic tasks.

B. Results of Qualitative Analysis

We would now like to turn to the actual reports and show in greater detail the ways in which the *Archaeotype* students displayed more effective argumentation. To begin with, they were more concerned with establishing, at the outset of their reports, key concepts in the research literature. Here, for example, is how one pair of students opened their report:

> Memory is a tool that can be divided into two parts, short-term memory and long-term memory. Short term memory is something that isn't very important to you, like when you tied your shoe today. Long-term memory is something you will remember for a long time, like HOW to tie your shoe.

Having thematized this distinction, they were then able to use it as an effective backdrop as they used more everyday kinds of expression to explain patterns in the various studies. Here, for example, is how they explained the last words/first words/middle words pattern in studies 1 and 2:

> The reason the last ones were the most popular was because they are the freshest in your mind. The words in the beginning are popular because you remember how it started, and also in the beginning you think you might think you can remember them all, but then you realize you can't.

In general, the *Archaeotype* students were more effective at integrating concepts from the research literature with their own notions about how things work. Consider, for example, how one pair of students described the effect of the unrelated task in study 3:

> In the exercises the people remembered the first few and the last few words except for in the exercise when they had to do something for thirty seconds before writing the words down. In that exercise the people did not remember the last words, which shows that these words (the last words) were remembered in their very short-term memories. They remembered the first words because they didn't have a jumble of words already in their heads.

There is a good deal of charm in this mingling of a technical concept such as "short-term memory" with a pungent expression such as "jumble of words already in their heads." But, more importantly, such mingling provides evidence that the students have actively assimilated the concepts from the research literature and are able to express them in everyday language. Consider, for example, how one girl was able to talk about the concept of short-term memory in a class discussion of the memory studies that was held after the reports were handed in:

> In doing the first study we thought that a reason people might have said the last words first was because they were stored in their short-term memory...because you know you can only remember things in short-term memory for a certain amount of time. Take a 7-digit telephone number, it's hard to remember for a while; if you get interrupted even for a couple of seconds, it will just go right out of your mind. So in this study we think the things in the short-term memory came out first because you can't remember them for long, and somehow they managed to switch over to long-term memory where they had stored the first words they heard.

The impressive texture of such improvised talk comes from the effective integration of terms such as "short-term memory" with everyday expressions such as "go right out of your mind." It seems evident that this girl not only understands what she has read in the research literature but is able to bring it to bear in interpreting the memory studies. The *Archaeotype* curriculum has apparently served her well in fostering a disposition to use everyday modes of thinking to explore technical concepts from research literature.

By way of contrast, students in the Control group were more cautious in their use of the research literature. Consider, for example, the way in which one pair of students introduced the third study in relation to the previous two: "Study three deals with long-term memory, while studies one and two deal with short-term memory." This rhetorical framing has considerable promise but it is not acted upon: the students simply describe the *first words/ middle words/last words* pattern but make no attempt to explain how it illustrates the use of long-term memory. In effect, the students dutifully included the technical concepts but provide no evidence of how they are relevant to the study under consideration.

The students were asked to end their reports with "practical recommendations for other students about how to improve their memories." Here, too, the *Archaeotype* students were better able to integrate data from the studies with technical concepts from the background readings. Before writing their recommendations, one pair of students provided an overview of the data in a section they entitled "Complete study analysis" (we see here the instinct to establish global coherence). They first delineated the crucial variables in the various studies—the greater time in study 2, the distracting task in study 3, the presence of associated words in study 4—and then moved on to a thoughtful discussion of long-and short-term memory. They closed this discussion by observing that:

> Long-term memory is something that comes naturally, like basic math facts and basic spelling are unconsciously put into long-term memory. Short-term memory is something that is forced.

Having used the technical concepts in a global analysis of the four memory studies, the students then turned their attention to the recommendations. They presented a range of techniques related to their prior discussion but then introduced an important technique—

visualization—that is unfortunately underrepresented not only in their report but all the others as well:

> Sometimes pictures or scenes can be formed in the mind using words listed or heard. These pictures or scenes can be repeated in the mind *with ease* [italics ours], therefore helping you remember.

Discussion

Both the quantitative and the qualitative results showed an impressive ability on the part of the *Archaeotype* students to create explanations of observations and argue for the validity of those explanations using a mixture of their own terms and ideas, and the technical terminology and concepts provided by background readings in a research literature. They also did well in recognizing patterns in the observations, but not significantly better than the Control group we compared them to. In fact, the similar performance of the Dalton School *Archaeotype* students and the Grace Church School Control students on the Pattern Recognition portion of the assignment provides assurance that the two groups were comparable, which makes the much higher performance of the *Archaeotype* students on Explanation-Argumentation all the more impressive. However, we need to also recognize that the basic patterns in the observations the students were analyzing were fairly easy to see—particularly, after the demonstration and discussion conducted by the experimenter in the beginning of the sessions. It may be that if the patterns being searched for had been less apparent then there would have been more of a difference in Pattern Recognition between the *Archaeotype* students and the Control students (see the results of the *Galileo* study reported next).

The *Archaeotype* students actually did worse than the Control students in Data Representation, although both groups scored rather low in this area. It is disappointing that the *Archaeotype* students did not use even such rudimentary ways of representing data as counts, means and proportions; assignments introducing such techniques should be incorporated into *Archaeotype* activities where appropriate. At least some students in the Control group managed to do some counting and means through entering the observations into a computer database program they were accustomed to using. Ideally, students would even have used visualization techniques like graphs and diagrams to reveal patterns in the observations and to argue for their explanations. At appropriate points in the unfolding curriculum, *Archaeotype* would be a natural context within which to introduce the powerful idea of representing information in different forms to gain insight.

I.2 Galileo—*11th and 12th Grade Science*

In the *Galileo* program, students (particularly students who are not scientifically oriented) learn about science and scientific reasoning by testing hypotheses against observations they make of authentic telescopic plates and a computer simulation of the sky and astronomical objects. The students work in groups to make observations and analyze the plates and simulation, then they write reports giving their observations, analyses and interpretations. The teacher models the scientific and astronomical reasoning, then coaches the students and serves as one of the information resources for them.

In this study, Dalton High School students were required to interpret and link three related cognitive psychology studies and their underlying principles. The students were given booklets containing descriptions of the basic observations made in these three psychology studies, together with various informational resources, including relevant and irrelevant background material. Students were given three hours to perform the task and write a final report. These reports served as a measure of the students' abilities to recognize specific patterns in the data and argue or explain the cause and effects of these patterns, as well as represent the data to support or refute their interpretations.

Overall, our results indicate that the 11th and 12th graders who have completed one year of the *Galileo* program performed significantly better on all three measures than their 10th and 11th grade counterparts, who will complete the *Galileo* program next year. The most telling indication of the success of the *Galileo* program is the difference in overall mean scores between our experimental group and the control one. The *Galileo* group showed a 33% advantage when compared to the pre-*Galileo* control group (these scores are from a total of 60 possible):

***Galileo* Group**	**26.1**
Control Group	**19.6**
33% advantage for *Galileo*	

The significance of these overall differences suggests that the interpretation-construction design underlying the *Galileo* program enhances students' abilities to think critically as well as to apply these skills to other knowledge domains.

Method

Participants

Our experimental group consisted of 46 11th and 12th grade students at the Dalton School who were at the end of the *Galileo* course. Our control group was 33 Dalton 10th and 11th grade students who plan to take the *Galileo* course next year.

Materials

The subjects were provided with copies (see Appendix B.1 for the assignment booklets used) of data from three cognitive psychology studies. In all three of these studies, the researchers select six students and have them memorize a list of 12 subject-verb-object propositions. However, the studies differ in the following ways:

Study One: One full day after remembering the list, participant memory is tested with items on a computer screen. The propositions appear in the same form as they were memorized. The computer records how long it takes each participant to respond with an affirmative answer.

Study Two: A different set of six students is asked to recall the propositions they memorized a day before; however, this time, they are tested with the passive voice version of the sentences instead of the active voice version they memorized. Once again, the computer records how long it takes each participant to respond with an affirmative answer.

Study Three: Yet another set of six students is asked to recall the propositions they memorized earlier; however, in this study, participants are tested with paraphrases of the sentences memorized and asked to respond "yes" if the test sentence has essentially the same meaning as the memorized sentence.

Upon reading the studies and background materials, students were asked to interpret the data. The background readings included descriptions of information processing systems and propositional network theory. Irrelevant information was also included.

Procedure

Administering the Materials and Collecting Student Reports

The study was conducted in one 3-hour session. First, the experimenter passed out the assignment booklets (Appendix B.1), the students were grouped by the teacher (into groups of 3 or 4), and the teacher read the instructions on the first page of the assignment booklet. After the instructions, the students proceeded to work on the assignment in their groups. While doing the assignment the students were free to use any of the resources in the Dalton School building (computers, libraries, etc.) including asking the experimenter for clarification (the same experimenter and teacher conducted all sessions). At the end of the period, the students handed in their reports and all the work they had done in folders.

Analysis of Student Reports

We performed both quantitative and qualitative analyses of the reports produced by the students in the sessions. In the quantitative analysis we devised a scoring scheme for assigning a series of numbers to each report, while in the qualitative analysis we examined the content of the reports for the meaning behind the numerical patterns observed.

A. Quantitative Analysis of Student Reports

The file folders from both the *Galileo* and pre-*Galileo* groups were evaluated along the following three dimensions: pattern recognition, explanation and argumentation, and data representation. As discussed earlier, these three dimensions were respectively weighted 2:3:1 based upon levels of difficulty. More specifically, groups could earn up to 20 points for pattern recognition, 30 points for argumentation, and 10 points for data representation. Extra credit points were awarded for plausible recommendations for follow-up studies on the cognitive psychology principles being tested; how-

This significantly superior performance of the Galileo group also occurred in all three of the component scores: namely, in Pattern Recognition (9.8 vs. 7.7—out of a possible 20), $t(77)=2.40$, $p<.01$; in Explanation and Argumentation (14.2 vs. 11.8 — out of a possible 30), $t(77)=1.69$, $p<.05$; and particularly in Data Representation where the pre-Galileo control group effectively got 0 (specifically, 0.1) whereas the Galileo group got 21% of the possible (2.1 out of 10 possible), $t(77)=6.14$, $p<.001$.

ever, a majority of the students did not address this aspect of the data.

Because our grading criteria were exceptionally stringent, scores ranged from as low as 6 out of 60 points to as high as 47 out of 60 points. Using our coding system, we were able to weigh answers in terms of difficulty as well as plausibility. The "optimal" responses for pattern recognition,explanation and argumentation, and data representation are as follows (see Appendix B.2 for the scoring sheets used).

Pattern Recognition:

Study One: Students should recognize that the response time increases with the number of propositions per subject. For example, if a lawyer has 3 propositions and a doctor has 2 propositions, then subjects will take longer to remember a proposition about the lawyer than the doctor. They are also expected to report the means. Partial credit is given for alternative patterns. *Maximum points: 4.*

Study Two: Students should note that the positive relationship between number of propositions per subject and response time still holds. They should also recognize that study two takes longer than study one. Again, means should be reported and partial credit is given for alternative patterns. *Maximum points: 7.*

Study Three: Students should recognize that the positive relationship between number of propositions per subject and response time still holds. They should also note that study three takes longer than study one and study two. Ideally, students should note that study three has a steeper climb (i.e., slope) than the other two studies. Means should be reported and partial credit is given for alternative patterns. *Maximum points: 9.*

Explanation and Argumentation:

Study One: In this study, the optimal responses would relate the information processing (links and nodes) and/or propositional network theories to the pattern recognized. Partial credit was given for responses favoring individual differences (contextual). Testing one's hypothesis (either rejecting or accepting) was also credited. *Maximum points: 6.*

Study Two: Students were supposed to relate the increase in mean response time to the stage of transforming a proposition from passive to active tense. They should have also noted that it takes time to match the transformed proposition to the database. Again, students were given points for appropriately using information processing theory or propositional network theory to support their hypotheses. Partial credit was given for responses favoring individual differences. Regardless of final outcome, hypothesis testing was also given partial credit. *Maximum points: 12.*

Study Three: Students were given credit for discussing how the overall increase in mean response time is due to an increase of search time, which is caused when a synonym for the original proposition is put in the recall test. They also should have noted that the increase time is due to the time required to match the synonym against the database. Students were given credit for using relevant background reading. Partial credit was given for responses favoring individual differences. Partial credit was also given for reporting hypothesis test and results. *Maximum points: 12.*

Data Representation:

Groups were given credit for creating spreadsheets that reported means and/or ratios, bar graphs that appropriately represented the data, propositional network diagrams, and alternative ways of representing the data to support explanations for trends. Ideally, students should have been creating graphs that reflected the differences between studies. By plotting these trends, students would have recognized that the intercept of study one and study three are the same but their slopes are different. Additionally, the intercept of study one and study two are different but their slopes are parallel. Representation of these trends was likely to have improved both the pattern recognition and argumentation scores. *Maximum points: 10.*

Recommendations:

Students were given extra credit for recommending plausible and relevant follow-up studies.

B. Qualitative Analysis of the Student Reports

In the qualitative analysis we examined the content of the student reports and collected excerpts to illustrate what the reports were like.

Results

Results of Quantitative Analysis

We report the overall results, then report how the results differed for each of the studies described in the experimental materials (the assignment booklets). Table 2 gives the overall results of the quantitative analyses. The total possible points was the same as in the *Archaeotype* study—namely, 60 points possible overall, broken down into 20 possible points for Pattern Recognition, 30 possible for Explanation and Argumentation, and 20 possible for Data Representation. As the first column in Table 2 shows, in total the *Galileo* group scored 33% higher than the pre-*Galileo* Control group (26.1 vs. 19.6—out of 60 possible), and this is statistically a very significant difference, $t(77)=4.56$, $p<.001$.

Table 2: Quantitative Analysis of Reports Written by Students in the *Galileo* Group and the Control Group

	Total	Pattern Recognition	Explanation and Argumentation	Data Representation
Galileo	26.1	9.8	14.2	2.1
Control	19.6	7.7	11.8	.1

This significantly superior performance of the *Galileo* group also occurred in all three of the component scores: namely, in Pattern Recognition (9.8 vs. 7.7—out of a possible 20), $t(77)=2.40, p<.01$; in Explanation and Argumentation (14.2 vs. 11.8 — out of a possible 30), $t(77)=1.69, p<.05$; and particularly in Data Representation where the pre-*Galileo* control group effectively got 0 (specifically, 0.1) whereas the *Galileo* group got 21% of the possible (2.1 out of 10 possible), $t(77)=6.14, p<.001$. Now in the following sections, we examine how the Pattern Recognition and Explanation and Argumentation results vary in the student reports corresponding to each of the three studies described in the experimental materials (the assignment booklets), then we examine these intriguing Data Representation results in more detail and discuss the student recommendations for follow-up research.

Pattern Recognition & Explanation and Argumentation:

Study One: The mean performance of *Galileo* students on pattern recognition was approximately 59 percent (2.4 out of 4). Pre-*Galileo* students averaged 47 percent (1.89 out of 4). The *Galileo* students were more likely to recognize that the recognition memory is quicker when there are fewer propositions to remember about a subject. They were also more likely to report the means, and use these means to support their explanation of the pattern. *Galileo* students were also more likely to use the *Excel* spreadsheet program to calculate means and identify the patterns inherent in the data.

Galileo students also did significantly better than pre-*Galileo* students in the argumentation section of the report. The former group averaged approximately 50 percent (3.0 out of 6); the latter group 33 percent (2.0 out of 6). This between-group difference can be partially explained by the *Galileo* students' higher scores on the pattern recognition section. However, it can also be attributed to the high-level hypothesis testing skills of the *Galileo* students. They were more likely than their pre-*Galileo* colleagues to generate and integrate different explanations of the data.

Study Two: Overall, the *Galileo* students averaged 4 points out of a possible 7 (54 percent) on the pattern recognition dimension; the pre-*Galileo* students averaged 3.2 out of 7 (46 percent). Based upon our criteria, *Galileo* students were more likely than the pre-*Galileo* students to recognize a positive relationship between the number of propositions and the response time. They were also more likely to report that the pattern identified in study one was maintained. Once again, *Galileo* students were more likely to report means and use them as support in the argument section of the test. Lastly, pre-*Galileo* students were less likely to report that study two resulted in greater overall response times than study one.

Interestingly, in the argumentation portion of the second study, the pre-*Galileo* students averaged 5.3 out of 12 points (44 percent) whereas the *Galileo* students averaged 4.8 out of 12 points (40 percent)—this is not a significant difference. It seems that both groups were able to articulate the cognitive mechanism driving the pattern and utilize background materials appropriately. Both groups understood that the stage of transforming from passive to active takes time. They also seemed to comprehend that making a match against the database increases time.

The results of the argumentation section for study two indicate that both groups were sufficiently capable of incorporating the background readings into their arguments. That is, although the pre-*Galileo* students may not have articulated the pattern, they were aware that there is a cognitive mechanism responsible for the overall increase in times between study one and study two. For example, one pre-*Galileo* group recognized that the additional increment of time in study two was due to the information processing stages discussed in the background material.

<u>Study Three</u>: Overall, *Galileo* students averaged 3.4 out of a possible 9 points (38 percent) on the pattern recognition dimension; the pre-*Galileo* students averaged 2.7 out of 9 points (29 percent). In general, *Galileo* students were more likely than pre-*Galileo* students to report that there is a positive relationship between the number of propositions and the response time. They were also more likely to generate means using the *Excel* spreadsheet program and report these means as evidence for the pattern. Although most students recognized that study three takes longer than studies one and two, neither the *Galileo* nor the pre-*Galileo* groups noted that study three has a steeper climb than the other two studies. However, graphs created by several *Galileo* groups represented this trend effectively.

Overall, *Galileo* students averaged 6 out of a possible 12 points (50 percent) in the argumentation section. The pre-*Galileo* students averaged 4 out of 12 points (34 percent). Once again, these results suggest that *Galileo* students were better able to provide support for the patterns in the data.

Data Representation:

Overall, the *Galileo* students were more likely than the pre-*Galileo* students to represent the data graphically. As suggested earlier, the former group used *Excel* to create spreadsheets and manipulate means and ratios. However, contrary to our expectations, very few groups went further than the creation of spreadsheets. Several *Galileo* groups plotted graphs using the data provided. These graphs may have helped them recognize several important patterns in the data as well as argue for them convincingly. We had hoped to see more graphic representations of the data.

<u>Graphs</u>: Ideally, we had envisioned students generating the following equations and being able to plot them on a line graph that clearly represented the intercept and slope differences that were embodied in the differences in the studies:

<u>Study One</u>. Response Time = 0.2(# of propositions) + 0.9

<u>Study Two</u>. Response Time = 0.2(# of propositions) + 1.2

This equation reflects how the passive-active transformation affects the intercept or query processing stage.

<u>Study Three</u>. Response Time = 0.4(# of propositions) + 0.9

This equation shows how meaning-judgment manipulation affects the slope or the memory item searching stage.

These three equations could be represented in line graphs as shown in Appendix C, Figure 1.

Neither *Galileo* nor pre-*Galileo* groups used line graphs for the equations. However, the bar graph shown in Appendix C, Figure 2, was prepared by a *Galileo* group and awarded maximum credit on the data representation section. This bar graph does not represent the underlying functional relation as well as line graphs would have, but it does capture the essence of the relationships.

Propositional Network Diagrams: Some groups used propositional network diagrams to help them understand and explain their data. An example is provided in the background materials. Figure 3 in Appendix C is a propositional network diagram created by a *Galileo* group.

Spreadsheets: Practically all of the *Galileo* groups used *Excel* to generate means and ratios. Only one pre-*Galileo* group used a spreadsheet to lay out and interpret the data. Appendix C, Figure 4, gives an example of a spreadsheet used by a *Galileo* group.

Flow Charts: Our coding scheme awarded points for flow charts; however, neither the *Galileo* nor the pre-*Galileo* groups used this form of data representation.

Alternative Representations: One *Galileo* group favored a contextual explanation of the data. The diagram that they developed to represent their hypothesis was too idiosyncratic to be categorized, and not clear enough to be reproduced—but it contributed significantly to the organization of the argument and was awarded partial credit.

Student Recommendations:

The *Galileo* students were significantly more likely to recommend plausible follow-up cognitive psychology studies. The criteria for crediting these recommendations were that these follow-up studies had to be relevant to the studies presented as well as realistic. Here are some examples:

- Use the same subjects for all three studies.
- Change the subject rather than the verb.
- Use longer, more complicated sentences.
- Use conjunctions.
- Use meaningful and nonsense sentences.

Summary of Quantitative Results:

Although our coding scheme privileged answers grounded in propositional network theory and information processing theory, students were given partial credit for recognizing individual differences in recall. For example, several *Galileo* and pre-*Galileo* groups noted that a proposition's salience (rather than frequency) influenced subsequent recall. While these are not answers we were "looking for," they are valid and were credited as such.

In evaluating responses involving pattern recognition and argumentation dimensions, it seems clear that some students used the background material as well as their own personal experiences to derive alternative hypotheses. For example, one group of students focused on the appearance of verbs and objects in the proposition (they were supposed to notice patterns based upon the number of propositions per subject). Although this was an incorrect assumption based on the data, their ability to test and reject their hypothesis was awarded credit.

A minority of groups favored an individual-differences perspective of the results and were awarded partial credit. Some argued that certain subjects would be more likely to recall "lawyer" than "mechanic" due to career aspirations. Others argued that childhood experiences affect word salience and recall. And one *Galileo* group noted that memorable words were embedded deeply in popular "Americana" culture.

> The *Galileo* students tended to integrate and elaborate upon the background readings in their own words. The pre-*Galileo* students tended to quote directly from the background materials or assumed the reader would refer directly to them.

Indirectly, many students also alluded to schematic principles. For example, one group of students explained that differences in means were due to one's association with the subject. By drawing a schematic diagram (see alternative patterns), this group attempted to discover a pattern in the data as well as support their argumentation section.

Results of Qualitative Analysis

Based upon the overall quantitative results, it seems that the *Galileo* students are more capable of recognizing patterns and providing evidence for their hypotheses than pre-*Galileo* students. The former group is more likely to accurately work with means and ratios as well as report these numerical representations in their final reports. They are also more likely to use spreadsheets and diagrammatic representations in order to support or refute their hypotheses. *Compare and contrast the following examples of* Galileo *(G) and pre-*Galileo *(PG) mathematical representations. Notice the superiority of the former students' ability to plan and analyze their own data manipulations.*

> G7—The first and most basic step that should be taken in order to determine whether or not there is any evidence of the node-link system produced by the tests on these six individuals is finding the average time it took each student....In this way, we can

determine if there is any basic common trend that persists in all of the students' methods of processing the question at all." *Notice that these students are using means in order to test the original hypothesis as well as identify patterns in the data. The "node-link" terminology shows that the students are integrating the background information into their own thinking.*

G19—...We became curious as to the relationship between the original times and the time it took to complete the studies that required more thought re-actions, causing higher response times. It occurred to us that perhaps, if we accounted for the time necessary to perform more difficult operations, we might find that reaction time would be similar to the original reaction time. To discover if a relationship existed, we began by taking group one as a control group and comparing it to group two....much as we had expected, the numbers came out to be quite similar." *Note in this case, the students have an excellent grasp of experimental design as well as mathematical applications.*

> Whereas the *Galileo* students often attempted to prove or refute the claims made in the background materials rather than accept them as valid, the pre-*Galileo* students were less likely to question the validity of the background materials and were, therefore, more likely to include irrelevant material in their final reports.

G13—The ratios showed (that the shortest times were for words that appeared once and the longest times were for the words that appeared three times in the list) because for the subjects that were repeated three times, their change in response time was even more extreme between study one and study three because there was so much for the students' minds to register (i.e., object time as well as sorting out between repeated subjects)." *Here, we see that the* Galileo *students are able to translate the background material into their own words. This enables them to help interpret their data.*

G12—We proved the preliminary assumption, the more memory units one has learned about someone or something, the longer it will take to remember them later. We averaged the response time...in order to manipulate one number only. This allowed us to review the results more easily. We set up the spreadsheet so that we could more easily compare the different values for each study. Finally, we set up another spreadsheet that would enable the determination of the validity of the preliminary assumption for the experiment. (Then) we analyzed the results of the spreadsheet. The last spreadsheet shows us that the students spent more time recalling the statements in study three than in study two, which took longer than recollection times for study one." *Note the use of averages to make the data easier to work with and the repeated use of spreadsheets as an analysis tool.*

PG3—"The response times...were the longest out of the six different test propositions for 'lawyer' and 'teacher,' whereas the response time for 'actor,' which only appeared once, was the shortest." *Notice that this pre-Galileo group was able to get the gist of the pattern recognition but did not use mathematical computations as support.*

PG22—"Those sentences containing subjects that occurred once in the original lists had lower times in study three than in study two." *Once again, no numerical representations are presented: the pattern of results is discussed only in vague, general terms.*

In summary, the *Galileo* students showed the ability to systematically organize and represent the data in ways that allowed them to test and evaluate the hypothesis based on the observations and relate all of this to relevant information in the background material.

Students work together on a task assigned by Malcolm Thompson for his *Galileo* class

Unlike the pre-*Galileo* students, the *Galileo* students were more likely to challenge theories provided in the background materials; they showed critical thinking in the sense that they would not merely accept what they were told, but examined it skeptically. Here are some examples:

G20—(In log report) "Upon reading the section titled, 'memory units in psychology', (one group member)...disagreed with the propositional network. We had a discussion about the patterns in which we thought." *To test this theory, the group calculated the study means and, ultimately, accepted the propositional network theory as grounded. This particular example demonstrates the Galileo group's superb ability to test and reject alternative hypotheses using mathematics as well as scientific principles. Moreover, the group exhibited excellent critical thinking skills.*

G15—"Can these theories be conclusively proven? Do these falsified data have any grounding in reality? We are basing our study on the comparison between the brain and the computer. Where a computer will take a longer time to process information if there are several propositions for one subject...we found for each group of sentences there were two subjects that were used in one, two or three sentences. Those subjects that were used three times were slower than the subjects used two times, which were slower than the ones used one time. This was valid for both students in every study." *Again, this group also used mathematics to recognize patterns and support hypotheses. However, the charm of this particular passage is that the students were reluctant to accept the theory as a given but rather wanted to test its assumptions. This is a skill that the* Galileo *program encourages.*

Some of the *Galileo* students also went beyond the basic patterns in the data to look for background-knowledge effects. These effects are real so the students were showing considerable insight in proposing them; however, they were not well reflected in the current data. *Here are some examples:*

G 1—"Another factor that would and it seems did affect the results is the logic of the sentences...but there do seem to be anomalies. We have theorized that the explanation for these discrepancies can be traced to the origin of the control group. They were all American students and so, in some way, they have generally the same experience with popular culture." *To explain anomalies in their own theory, this group attempts to reformulate the data to make it fit. The group argues that its "the key word" theory, is "supported by the information concerning links and nodes that were also contained within the background pages. These words (e.g., 'candy' and 'baseball' on the second test) are nodes...heavily linked throughout the brain and so they are connected faster and so they are identified better." This group's ability to incorporate the background materials is laudable and their argument for both pattern recognition and explanation is plausible. For this reason, they were given partial credit for their responses.*

G13—"We thought of the possibility that different subject-verb-object combinations could affect time in the studies. For example, does it affect response time if the teacher were giving the test or playing baseball? But because we only see the students' results regarding one subject for each list, we didn't know how to approach it." *Here, the group seems to be indirectly referring to schema-theory. That is, certain associations between subjects and objects and/or verbs are stronger than others. There is also a recognition that strengths of such associations vary with individual life* *experiences. G1 also seemed to be implying a similar idea.*

Discussion

In general, both *Galileo* and pre-*Galileo* reports seemed to reflect an understanding of hypothesis-testing generation and refutation. For example, two *Galileo* groups argued for a contextual interpretation of the data based upon their own self-reflection. Another group tested the hypothesis that altering a common verb or object will affect recall. One member of this group tested this hypothesis on several students in the hallway; based upon these results, the group rejected the hypothesis.

Overall, the *Galileo* final reports were more clearly written than the pre-*Galileo* ones. The *Galileo* students tended to integrate and elaborate upon the background readings in their own words. The pre-*Galileo* students tended to quote directly from the background materials or assumed the reader would refer directly to them. Being able to discuss things in one's own words indicates a better understanding of the material, so the *Galileo* students seemed to get at the meaning behind the technical terminology in the background readings better than the pre-*Galileo* students.

Galileo students tended to understand the theories presented in the background materials better than their pre-*Galileo* counterparts. They were also more likely to challenge these theories through their own analyses and argumentation of the data. Whereas the *Galileo* students often attempted to prove or refute the claims made in the background materials rather than accept them as valid, the pre-*Galileo* students were less likely to question the validity of the background materials and were, therefore, more likely to include irrelevant material in their final reports.

In general, on average across the three studies, the quality of the arguments made by the *Galileo* student reports was better than of those presented by the pre-*Galileo* students. However, it is interesting to note the results of study two. For that particular study, there was very little difference between the *Galileo* and pre-*Galileo* groups. This may be due to the comprehensibility of the background materials on the query processing stage versus the memory item searching stage.

Overall, *Galileo* students were more capable of recognizing patterns and providing evidence for their hypotheses than pre-*Galileo* students were. Generally, the *Galileo* students were more likely to accurately work with means as well as report them in their final papers. This seems to suggest that the *Galileo* students are quite comfortable with these simple mathematical manipulations and interpretations of the data. However, neither pre-*Galileo* nor *Galileo* students used the most insightful representation to gain deeper insight into the phenomenon; namely, they did not use line graphs to discover the underlying mathematical functions behind the observations and to use these functions to move to a more sophisticated understanding of the patterns and explanations of them. More emphasis on graphs and functions would seem like a natural and valuable extension for the *Galileo* program. *Galileo* seems like an excellent context to make graphs and functions more meaningful to non-mathematical students.

I.3 *Conclusions From Group Comparison Studies of* Archaeotype *and* Galileo

> The only result in this study that might be construed as negative pertains to the category "data representation." Both *Archaeotype* and *Galileo* students fell short of expectations in this area, with *Archaeotype* students actually outperformed by the Control group. A close look at the research procedure suggests an explanation that reveals the unique place of the computer in the Dalton Technology Plan. The control group in the *Archaeotype* study had been taught, in a conventional computer course, to use a spreadsheet program—and they used it. But there it ended. The data thus displayed played no role in their thinking. *Archaeotype* students, on the other hand, weren't applying computer routines at all; they were doing quite spontaneously what they had actually learned to do—think for themselves. The full significance of the 73% advantage for the *Archaeotype* students in the "explanation and argumentation" category stands out against the background of the "deficit" in a domain-specific "computer skill." Does that mean that the Dalton Technology Plan discourages the use of routine data processing? Of course not. It only means that the acquisition of such skills must be integrated into a substantive educational context.

Overall, Dalton students in the *Archaeotype* and *Galileo* programs performed much better than other comparable students on assignments that required them to find patterns in observations in a new topic area (psychology), create explanations of those patterns and argue for the validity of those explanations, and represent the observations in ways that provided insight. The *Galileo* students showed this superior performance across all three of these areas (Pattern Recognition, Explanation and Argumentation, and Data Representation), while the *Archaeotype* students only showed significantly better performance in the Explanation and Argumentation area. The *Archaeotype* students were slightly (but nonsignificantly) better in Pattern Recognition. However, the basic patterns in the observations presented to the *Archaeotype* and Control students were fairly obvious, so it seems likely that given more obscure patterns the *Archaeotype* students (like the *Galileo* students) would also show significantly better Pattern Recognition.

However, the Data Representation area was another matter entirely. Here, even though the *Galileo* students performed better than the Control students, the level of performance was low. The *Archaeotype* students even performed significantly worse than the Control students. *Archaeotype* and *Galileo* (and the other Dalton Technology Plan programs) seem like natural contexts within which to teach powerful information representation strategies (i.e., ways of organizing information to provide insight), so we recommend that such strategies be embedded in future versions of these programs wherever it is appropriate.

In conclusion, the interpretation-construction design of the Dalton Technology Plan as implemented in *Archaeotype* and *Galileo* has produced impressive results in having students acquire powerful thinking skills. Seldom in educational research does one see differences the size of the ones between the Dalton Technology Plan student scores and Control student scores in these studies. However, some aspects of our results also indicated ways in which the Dalton Technology Plan programs can be extended to cover more thinking skills (specifically, information representation strategies).

Part II: Initial Analyses of Student Work and Proposals for Systematic Evaluation in Other Dalton Technology Plan Programs

In addition to the formal group-comparison evaluations of *Archaeotype* and *Galileo* that we reported in Part I, we also examined a few pieces of student work from each of six other Dalton Technology Plan programs. These other programs are not as fully developed as *Archaeotype* and *Galileo,* but the student work in all of them suggests substantial beneficial effects of the programs and therefore warrants full-scale, group-comparison evaluations in the future. In the following sections, we describe what student work we examined and the results of those examinations, then we give formative suggestions about how we think the programs could be improved or extended, and outline how summative, group-comparison evaluations (analogous to the ones reported in Part I) could be done. As in Part I, we have strived to design student assessments as part of the evaluations which are valuable educational experiences in themselves, not just tests.

II.1 *Computers and Geometry—7th Grade Math*

The Computers and Geometry program uses a scientific-experimentation approach to providing 7th grade students with an intuitive understanding of geometry as a precursor to the formal study of geometry later (e.g., in the 10th grade) and as a mediator for application of geometric understanding in a variety of contexts. This scientific-experimentation approach to teaching geometry involves presenting the students with a mathematical hypothesis (e.g., "a line drawn across two sides of a triangle parallel to the third side divides the first two sides proportionally"), then having them use the *Geometer's Sketchpad* computer program to systematically generate a series of cases to test the validity of the hypothesis (e.g., create a triangle and line parallel to a side, then use animation to generate a series of such triangles to see if the hypothesis holds for all of them). We call this a scientific-experimentation approach to mathematics because it is like doing a scientific experiment in physics or chemistry where one manipulates something then examines the effects on the physical world.

We examined three essays that students wrote for Assignment 4 in the class. Two of the three fit the framework we just described: that is, they explored the hypotheses they were given by using the *Geometer's Sketchpad* computer program to generate a few examples, then discussed whether they fit the hypothesis. For example, these essays had discussions like:

> "We first made a fixed, small triangle with the same angles as a fixed large triangle. What I mean by fixed is that the measurements never change. (I will not use the word

We also examined the student assignments we sampled in terms of the Geometry Section for Grades 5-8 of the National Council of Teachers of Mathematics (NCTM) standards. We emphasize that these standards are widely admired as an ideal (in fact, other fields are madly scrambling to produce something analogous using the NCTM ones as a model), but they are seldom if ever attained.

> 'similar' for the time being.) The second thing we did was duplicate the small triangle three times....The third thing we did was fit the three duplicates into the corners of the fixed large triangle. All fit perfectly. This proves that there are the same angles in the small triangle as in the big. Now for the unused word. The term for triangles in which all of the angles are equal to each other is that they are similar triangles...."

Such essays are unusual in math classes but are valuable in getting students to make their thinking explicit and thus more systematic and memorable. Particularly interesting in this example is that the student insists on using her own words for her work and only uses the technical terminology at the end—students who can express material in their own words have a better understanding of the material than those who cannot.

The third essay was excellent but it was a surprise because instead of geometry examples it offered formal proofs of the hypotheses. For example, this essay had discussions like:

> "We know that their slopes are equal because they are parallel to each other....The two sets of intersecting lines both have the same slope. Since the two sections are congruent, angle GDA must equal angle FAE, since they correspond to each other in the two sections...."

While in a formal sense, this student demonstrated a deeper understanding of the material, he did not seem to be seeing how these hypotheses worked in application to specific examples. While having a 7th grader who can do formal geometry proofs is terrific, we think that the student also needs to go through the process of example-generation to develop an intuitive understanding in addition to a formal understanding. Perhaps this student did that but did not include it in his essay, but we think there is also value to writing up the example results.

We also examined the student assignments we sampled in terms of the Geometry Section for Grades 5-8 of the National Council of Teachers of Mathematics (NCTM) standards. We emphasize that these standards are widely admired as an ideal (in fact, other fields are madly scrambling to produce something analogous using the NCTM ones as a model), but they are seldom if ever attained. Thus, attaining the standards is quite a feat. The NCTM standards for Geometry, Grades 5-8, are:

- identify, describe, compare and classify geometric figures;
- visualize and represent geometric figures with special attention to

Our examination...shows that they directly and successfully address the first three and the fifth of these six NCTM standards.

developing spatial sense;

- explore transformations of geometric figures;
- represent and solve problems using geometric models;
- understand and apply geometric properties and relationships;
- develop an appreciation of geometry as a means of describing the physical world

(Curriculum and Evaluation Standards for School Mathematics, NCTM, Reston, VA, 1989, p.118).

Our examination of the student essays from the 7th grade Geometry course shows that they directly and successfully address the first three and the fifth of these six NCTM standards. The fourth (or representation) standard is covered in terms of solving problems stated in an abstract geometry form, but is not covered in terms of application to other areas — which is also the subject of the sixth standard. Thus, the fourth and sixth standard — namely, the representation and application standards — are not addressed *in the student assignments we examined.* If it is not already done in other assignments, we recommend that the Computers and Geometry program be extended to cover generation of application problems and problems that show how to use geometric representations of information in a variety of topic areas. Perhaps the *Geometer's Sketchpad* computer program can be used to facilitate this or else software to facilitate it can be developed within the Dalton Technology Plan itself.

> "The other transfer study that needs to be done would examine whether the students in the Geometry course have developed geometric intuition sufficiently that they naturally apply it in other contexts—for example, in other courses or in projects set up to test for such transfer in new topic areas (like the studies described in Part I of this document)."

The most exacting tests of the value of this course in building general geometric thinking skills would be to see if the students transfer what they have learned to a formal geometry class and to other courses. The first transfer study would be to examine whether the students who have been through the 7th grade Computers and Geometry course do better in a later formal geometry class (say, in the 10th grade) than students who have not been through the Computers and Geometry course. We recommend that a formal study be done later to make this comparison when the current students take the formal geometry course. The other transfer study that needs to be done would examine whether the students in the Geometry course have developed geometric intuition sufficiently that they naturally apply it in other contexts—for example, in other courses or in projects set up to test for such transfer in new topic areas (like the studies described in Part I of this document). Ideally, students in the course would have made geometric thinking such a natural part of their intellectual repertory that they would, for instance, look at pictures of biological organisms and see similar triangles, that they would visualize alliances of countries in history in terms of the underlying geometry (e.g., the organization of the allied higher command reflected the triarchic nature of the alliance), and so forth. While it would be unfair to look for such transfer until the Computers and Geometry program is sufficiently developed, we recommend that such comparison studies be done in the future (perhaps even an initial one next year).

II.2 *Civil War CD-ROM—12th Grade History*

The *Civil War CD-ROM Project* strives to give students a deeper understanding of the Civil War and history in general by having them construct multimedia essays on the computer using a variety of primary source materials and commentaries. To examine the effects of this *Project* on students, we compared four essays written about aspects of the Civil War by Dalton High School students who did not participate in the *Project* with three essays written by students who did. We also compared both of these kinds of written essays with two multimedia essays created by *Project* participants. All of these essays are similar in the sense that they are well-structured with the students making one or more points and cogently arguing for them using lines of reasoning and drawing upon supporting information.

However, the three kinds of essays are also strikingly different. The biggest difference between the *Project* essays and the non-*Project* ones is that the latter drew upon political speeches (e.g., Lincoln's) and books experts had written giving their interpretations of the events, whereas the *Project* essays relied heavily on primary reports by participants in the events (e.g., diaries, local church publications, and photographs). All of the non-*Project* essays used books about the events, while two of the three *Project* essays were written using primary reports. The third written *Project* essay uses secondary materials like the non-*Project* ones, but focuses on the limitations of such materials. Thus, in general, *Project* students used primary reports of participants in historical events to construct their own interpretations of the events (while drawing on expert commentary as appropriate), while the non-*Project* students organized how others interpreted the events, then drew conclusions from that.

> We predict that if we set up a mock trial situation and placed students who have produced hypermedia knowledgebases like the *Women's History* one and students who have not had that experience in various roles (juror, prosecution, defense, judge) in the trial situation, then the hypermedia-knowledgebase-savvy students would show markedly superior performance to other students.

One of the multimedia essays is similar to the *Project* written essays in that it is essentially a linear piece, but the multimedia computer environment it is implemented in allowed the student to annotate this essay with photographs and excerpts from the Ken Burns video *The Civil War* (which is actually also a series of photographs with music and voice-over). While this essay shows the historiographic awareness built into the course, it is not so much about the Civil War as it is about how biases can enter into seemingly realistic and neutral photographic accounts of events, people and settings. In fact, this essay illustrates a potential danger that arises when flashy, high-tech multimedia capabilities are introduced into a study environment—namely, the new media tend to seize control sometimes to the detriment of the topic being studied. Thus, in this case we get an essay on the media aspects of photographs using photographs of the Civil War to illustrate how the biases relate to major issues of the Civil War.

Despite that media focus, however, this student did not use the hypermedia computer environment to its fullest potential; she effectively just wrote in a standard linear essay form with video and photographic annotations. A more sophisticated use of hypermedia would have the structure of the hypermedia essay reflect the content structure being communicated. For example, in this case the underlying structure is not linear at all, but is composed of two major pieces with no particular sequential order between them — namely, the part analyzing *The Civil War* video and the one discussing the still photographs. Within each of these parts there is a complex substructure. The initial screen for this essay would have reflected this content structure if it had given us a choice between an introduction, the video analysis, and the photograph discussion, then let us navigate through the material as we chose. The other screens could have similarly reflected the more detailed content structures of each of these major parts.

This kind of fuller use of hypermedia capabilities is found in the other multimedia essay we examined. This essay (purportedly about *Women in the NYC Draft Riots*) opens with a 5-point screen giving us a choice of how we want to navigate through it: we can start with essays on women's history, a report on the importance of teaching women's history, videos of interviews with students and faculty about women's history, background on the NYC Draft Riots, or primary reports of women's experiences in NYC during the mid-1800s. As this menu of topics indicates, calling this an "essay" does not do it justice: it is really a database, or more accurately a knowledgebase, containing a variety of information about the importance of women's history, with the mid-1800s (roughly the Civil War era) in NYC as an illustration. This knowledgebase seems a fuller realization of what can be accomplished in projects like the *Civil War CD-ROM Project*—namely, a richly textured, full-fledged exploration of a topic in detail with the structure of the hypermedia system created reflecting the content structure of the topic knowledgebase. Creating such knowledgebases seems likely to give the students a deeper understanding of the topic and history in general, while the hypermedia system itself provides a valuable information resource for them and others. However, we have to note that this knowledgebase is not really about the topic in the title *Women in the NYC Draft Riots*. It would be more accurately titled *NYC Women's History in the Civil War Era*. Perhaps when constructing such knowledgebases, one does not necessarily wind up where one intended, but that change of focus should be reflected in the title.

> Thus, while we do not have enough material here to make any firm conclusions, what we do have suggests that a more controlled and extensive evaluation study would show some big effects. Also, this on-line record of student work (and teacher coaching) would seem to provide a potential gold mine of information about the literary analysis and writing processes taking place here.

What thinking skills might the students have learned from participating in projects like the *Civil War CD-ROM Project* — particularly if they have been able to produce something at the level of this *Women's History* hypermedia knowledgebase? They seem to have learned to integrate primary narrative reports from event participants, photographic and video records, and expert commentary to come up with an interpretation of the events. But when in the course of everyday human affairs would one ever be called upon to do something like that? Well, participants in legal trials (e.g., the Rodney King case) are called upon to do this all the time. We predict that if we set up a mock trial situation and placed students who have produced hypermedia knowledgebases like the *Women's History* one and students who have not had that experience in various roles (juror, prosecution, defense, judge) in the trial situation, then the hypermedia-knowledgebase-savvy students would show markedly superior performance to other students. Such a formal study seems valuable to conduct in the future. However, we suspect that some more research and development is needed first to discover how to get *all* students creating hypermedia knowledgebases at this level of sophistication.

II.3 *Computers and Writing Process—4th Grade English*

Part of the 4th Grade at the Dalton School has participated in a *Computers and Writing Process* program in English. In this program, the approach is to have enough computers in the classroom so that students can individually plan, write and revise on the computer from the beginning (as opposed to writing by hand first, then transcribing onto the computer before final printing). We examined 20 book reviews provided to us from the *Computer* students in comparison with 17 picture reviews (students analyzed a picture they were given) from a non-*Computer* English class.

Structurally, the reviews from the *Computer* and non-*Computer* students were similar: they all gave an introduction stating an overview of the book or picture, or a reaction (e.g., "This picture...is dull", "...is a great book"); then reported the basic contents of the work (the composition of the picture or the plotline of the book); and provided a concluding statement. Thus, in terms of text structure the two groups were equivalent. They were also equivalent in overall, holistic quality ratings.

The reviews written by the *Computer* and non-*Computer* students did differ dramatically, however, in length and number of affective expressions. The *Computer* student book reviews were twice the length of those of the non-*Computer* students, and they contained an average of six affective expressions (e.g., "I liked this book"), while the non-*Computer* student picture reviews had almost none. However, it is hard to know whether to attribute these differences to the *Computer*/non-*Computer* difference or to the difference in topic. Clearly, students writing a review of a book they enjoyed would be expected to use more affective statements than students analyzing an assigned photograph. Also, reviewing a book is generally a bigger topic than analyzing a photograph, so the difference in length may be due to the size of the topic.

Thus, to make conclusions about the writing of the 4th Grade *Computer* and non-*Computer* students, we would need more comparable writing samples. For example, if we had each group write book reviews of books they liked (or even all write book reviews of the same book) for publication in a school newspaper or inclusion in a network database, then we would have a more comparable writing sample. However, it would probably be even better to have a writing sample composed of more than one kind of text — e.g., perhaps have each student give us a book review and a field trip report, such as, a report of a museum visit.

II.4 *Computers and Writing About Literature—8th Grade English*

In contrast to the 4th Grade writing program just described, this program focuses on having students work collaboratively in groups of four around computers to jointly analyze works of literature (e.g., *The Catcher in the Rye*), write an assignment using this analysis, and only then individually write three essays about some aspect of the work (and each of these essays goes through three drafts). Through all of these phases, the teacher accesses the student writing on-line and provides coaching annotations to what the students have produced. We examined one pathway through this *Collaborative-Computer* class; namely, we examined one Group Journal of observations, ideas and questions about the literary work; one Group Assignment that began to organize some of these observations and ideas; one first draft of an individual essay; and one third (final) draft of an individual essay. We compared these to four final-version essays from a non-*Collaborative-Computer* 8th Grade English class.

The pathway from the *Collaborative-Computer* class provided a clear audit trail of the writing process: proceeding from an extensive list of disorganized observations, ideas, and questions; through a clustering of some of these observations and ideas into thematic units; to an impressionistic first draft of an individual essay; and finally to a highly organized, very well-structured and closely argued final draft of high quality. The comparison essays from the non-*Collaborative-Computer* class were also polished and of high quality (even artful), but in terms of text structure they were more impressionistic, like the first draft from the *Collaborative-Computer* class, and did not have the crystalline organization of the final draft from the *Collaborative-Computer* class.

Thus, while we do not have enough material here to make any firm conclusions, what we do have suggests that a more controlled and extensive evaluation study would show some big effects. Also, this on-line record of student work (and teacher coaching) would seem to provide a potential gold mine of information about the literary analysis and writing processes taking place here—if individual student work were tracked through all these phases. In addition, while current software appears to be adequate, it was not designed to be used in this fashion. We think that with some thought (and research and development) Dalton could probably create software that would support the kinds of group analysis and discussion (and teacher coaching) activities embodied in this class much better than current software does.

II.5 *Conclusions From Initial Analyses of Student Work*

The student work in all of these programs showed enough promise to warrant future formal group-comparison evaluation studies (like the ones reported in Part I). As we have indicated, sometimes those studies can utilize assignments much like those currently used in classes, as long as the assignments are made more comparable across classes and collection of student work is done systematically — for example, book reviews and trip reports can be collected to evaluate the 4th grade *Computers and Writing Process* program, and essays on literary works like *The Catcher in the Rye* can be used to evaluate the 8th grade *Collaborative Analysis and Writing* program. With both these programs and the *Computers and Geometry* program, we would also expect to see effects in the other classes that the students take. In particular, we would expect the writing processes to be reflected in assignments done in other classes and more visual reasoning to be used there as well.

In other programs, it seems more useful to design separate assignments for use in program evaluation. Examples are the literary-transformation assignment for the *Playbill* program, the mock-trial assignment for the *Civil War CD-ROM* program, and the kinds-of-music-study assignment for the First Program. It would also be useful to design a visualization and application assignment for the *Computers and Geometry* program. With all these example assignments we illustrate our belief that tasks designed for student assessment and program evaluation should be valuable educational experiences in their own right — not just tests for the sake of testing.

Two of the programs seem as if they would benefit from further software development. Specifically, the *Computers and Geometry* program would likely be aided by having software to link geometric reasoning with real-world applications, and the *Collaborative Analysis and Writing* program would probably benefit from software that facilitated student collaboration and teacher coaching. In addition the *Computers and Geometry, Playbill, Civil War CD-ROM*, and First Program projects all seem to need additional instructional development to make them more effective.

***

Appendix A.1: *Archaeotype* Test Instrument

Introduction for Students

In school, you have learned many skills that apply to areas beyond those that you have covered in class. This assignment provides you with a chance to see how the skills that you have learned can be applied in another area, one that is new to you.

This document contains descriptions of a series of studies done by psychologists who have been studying how human memory might work. Your job is to examine these studies and the observations that the psychologists reported. Then you will present what conclusions you can based upon your observations, inferences, hypotheses and research into the background reading we will provide you. The ***Background Readings*** section contains information on related psychological studies and theories that will help you.

Write a report describing your hypotheses, your evidence and the line of reasoning that led you to your conclusions.

On the basis of your own conclusions, can you make any practical recommendations to other students about how to improve their memories?

First Study

In this study the psychological researchers brought together five students. The researchers read the students the following list of 20 words at a rate of one word per second. Here are the words that the researchers read to the students in the order in which they read them:

car, sky, apple, book, cup, lock, coat, light, bush, iron, water, house, tape, file, glass, dog, cloud, hand, chair, bag.

After the researchers read these words, they said: "Recall." At that time, the students wrote down as many of the 20 words as they could remember, in any order they liked.

Here are the words that the five students in the study recalled and the order in which they recalled them:

Student 1

bag, hand, chair, cloud, car, sky, light

Student 2

bag, chair, hand, car, sky, book, house, bush

Student 3

hand, bag, chair, cloud, car, lock, dog

Student 4

bag, hand, chair, dog, car, apple, sky, water, glass

Student 5

bag, chair, car, iron, apple, cup, water, light

Second Study

This study is the same as the first, except that now the researchers read the words to the students at the rate of one word every 3 seconds. The list of words and the number of students were the same as in the First Study. However, we will name these students numbers 6 - 10 to show that they are different people from the five students in the First Study. Once again, here are the words in the order they were read:

car, sky, apple, book, cup, lock, coat, light, bush, iron, water, house, tape, file, glass, dog, cloud, hand, chair, bag.

Here are the words that the students recalled in the order in which they recalled them:

<u>Student 6</u>

bag, hand, chair, dog, car, sky, apple, book, tape, file, house, list, bush

<u>Student 7</u>

bag, chair, hand, cloud, sky, car, book, apple, cup, lock, iron, glass

<u>Student 8</u>

bag, hand, chair, cloud, sky, car, apple, book, file, bush, coat, iron, tape

<u>Student 9</u>

bag, hand, chair, dog, car, sky, apple, water, cup, glass, house, bush, dog, book

<u>Student 10</u>

bag, chair, hand, cloud, sky, car, book, coat, water, light, lock, house

Third Study

In this study the researchers read the same list of 20 words to yet another group of five students. These new students were named students 11 - 15 to distinguish them from the previous students. In this study, however, the researchers did not tell the students to "Recall" immediately after reading the list of words. Instead they were asked to do another task first, which took 30 seconds. Immediately after this task the students were told to "Recall" as many of the words as they could, again in any order they liked.

Here again is the list of 20 words in order:

car, sky, apple, book, cup, lock, coat, ight, bush, iron, water, house, tape, file, glass, dog, cloud, hand, chair, bag.

Here are the words that the students recalled in the order in which they recalled them:

<u>Student 11</u>

car, sky, book, apple, bush, house, glass, chair

Student 12

car, sky, lock, iron, water, cloud, bag

Student 13

car, apple, coat, bag, hand, file

Student 14

car, sky, light, cup, tape, dog

Student 15

car, apple, cup, water, glass, house

Fourth Study

This study was just like the First, except that a different list of 20 words was read to the students, who then recalled them. The list used this time was:

coat, pear, chair, cow, bus, apple, pants, boat, dog, desk, shirt, car, table, horse, orange, shoe, train, cat, couch, banana.

Here are the words which the students recalled in the order in which they recalled them:

Student 16

banana, cat, pear, apple, orange, cat, dog, cow, horse, coat, shirt, shoe

Student 17

banana, couch, cat, dog, horse, coat, pants, shirt, shoe, pear, apple, orange, bus, train

Student 18

banana, pear, apple, cat, dog, cow, horse, coat, pants, shirt, chair, table, desk, bus, car, train

Student 19

banana, couch, cat, dog, cow, horse, coat, pants, shirt, shoe, pear, apple, orange, chair, table

Student 20

banana, couch, cat, coat, pants, shirt, shoe, pear, apple, orange, chair, table, desk, dog, cow, horse

Background Readings

Short-Term Memory

Psychologists who study how people remember make a distinction between short-and long-term memory. Short-term memory holds the information being actively thought about at any moment. It is a temporary storage area. Holding information in short-term memory does not necessarily lead to a more permanent memory that can be remembered some time later. For example, you might read a telephone number out of a telephone book and repeat it over and over to yourself while walking across the room to the telephone (thus holding it in short-term memory). However, if someone asks you what the number was just a few minutes after you dialed it, you probably won't remember it. This would happen because you merely held this number temporarily in short-term memory but did not process it deeply enough to transfer it to a more permanent form of memory. Note also that this form of memory has a limited capacity; merely holding a seven-digit telephone number strains its capacity.

This kind of memory is called "short-term memory" because you can only store material in this memory area for a few seconds unless you repeat it to yourself or you process it more deeply to transfer it to a more permanent memory. If someone had interrupted you even for just a few seconds as you were walking across the room repeating the phone number to yourself, you would find that you had forgotten the number and would need to go back and look it up in the phone book again.

Long-Term Memory

Psychologists call the more permanent form of memory "long-term memory" because it lasts for a long time. Information is transferred from short-to long-term memory by processing it more deeply—that is, by thinking about the meaning of what you are learning, figuring out how the parts of what you are learning relate to each other and figuring out how they connect to things you already know. For example, if you were trying to learn the following list of words—*door, table, list, woman, money, car*—you could try to learn it by just repeating it over and over to yourself, only paying attention to what the words look like and sound like (that is, processing the words only shallowly). But you would be much more successful in transferring it to long-term memory by noting its connection to your prior knowledge about what goes on in restaurants. Thus you can transform the meaningless list of words into the following meaningful story episode:

The man went in the restaurant *door*, sat down at the *table*, looked at the *list* of dishes, then gave his order to the *woman*. When finished, he paid her the *money*, and drove home in his *car*.

After creating such a story episode, the list of words is easily remembered later by remembering the story and pulling out the key words. Research by psychologists has shown that this is the most effective way to transfer information from short-to long-term memory —namely, notice a connection to something you already know, then use that prior knowledge to make it meaningful and link together the new information that you want to remember later.

There are many kinds of prior knowledge that you can use. One kind is scripts of actions for what happens in standard situations like going to a restaurant. Another kind is knowledge about categories like knowing that robins and pigeons are both birds. Yet another kind would be knowledge about motivations that allow you to understand why people do some things and not others. The kind of knowledge you use to understand new things doesn't matter, but using the knowledge to make the new things meaningful makes the difference in how well you will be able to remember it.

Ways To Remember Better

You can even take something as meaningless as a phone number and make it somewhat meaningful with a little thought. For example, suppose the phone number for your favorite pizza restaurant is *678-5346*, so you want to be able to remember it — and thus you want to get it into long-term memory. What you need to do is analyze this number into meaningful patterns which you can then use to recreate it later. Thus, you might note that the first three numbers form an increasing sequence starting from *6* — namely, *6, 7, 8*. Then you note that the last four numbers have another increasing pair *3,4* surrounded by yet another increasing pair *5,6* while the last number is the same as the beginning of the first three numbers *(6,7,8.)* You can then link all this together with the pizza restaurant by forming an image in your short-term memory of the pizza cook with *6,7,8* written on the front of his shirt juggling *3,4* and *5,6* instead of pizza dough. Psychological research has shown such integrating images to be very effective memory aids.

These kinds of memory "tricks" or "mnemonics" are used to make the meaningless become meaningful and thus transfer it into long-term memory so that it can be remembered later. They are really not tricks at all but applications of the basic memory principles discussed earlier.

Most information that you will need to remember later, however, has a meaningful organization of its own, so the best way to remember it is to uncover that meaningful organization. For example, when studying history, instead of trying to rotely memorize that the steam engine was invented and then the Industrial Revolution occurred, you can learn the fact better by noticing the meaningful relationship between the two events — namely, that the steam engine was needed to power the automated factories created in the Industrial Revolution.

Appendix A.2: *Archaeotype* Scoring Scheme

I. Pattern Recognition (20 points)

- A. Study 1
  1. last/first/middle pattern (middle attenuated) 1-2
- B. Study 2
  1. last/first/middle pattern (middle strengthened) 1-2
  2. overall increase 1-2
- C. Study 3
  1. first/middle/last pattern (last sharply attenuated) 1-2
  2. overall decrease 1-2

D. Study 4
   1. last + categories (last attenuated) 1-2
   2. overall increase 1-2
E. Other Patterns
   e.g., meaningful word pairs in studies 1-3; category salience in study 4;prototype cueing in study 4 1-6

II. Explanation and Argumentation (30 points)
A. Local Explanations (16 points)
   1. Study 1
      a. [-background reading] 1-2
      b. [+background reading] 1-4
   2. Study 2
      a. [-background reading] 1-2
      b. [+background reading] 1-4
   3. Study 3
      a. [-background reading] 1-2
      b. [+background reading] 1-4
   4. Study 4
      a. [-background reading] 1-2
      b. [+background reading] 1-4
B. Global Explanations (14 points)
   1. Overview of Studies
      a. [-background reading] 1-2
      b. [+background reading] 1-4
   2. Alternative Explanations 1-2
   3. Recommendations
      a. [+data] 1-4
      b. [+background reading] 1-4

III. Data Representation (10 points)
A. Numerical (4 points)
   1. Counts, means, etc. 1-2
   2. Proportions 1-4
B. Graphic Displays (6 points)
   Distribution graphs, tree structures, flow charts, etc. 1-6

Appendix B.1: *Galileo* Test Instrument

Introduction for Students

In school, you have learned skills that apply to many areas beyond the particular topics that you have covered in class. This assignment provides you with a chance to see how these skills can be applied in an area new to you.

This document contains descriptions of a series of studies done by psychologists exploring how human memory works. The basic question these studies address is what is a unit of measurement for human memory: that is, what is a way to measure how much information is contained in some material to be remembered. A number of psychological and philosophical theories claim that the basic unit is the proposition. A proposition is a set of objects or people and the relations between them. This idea is captured in its most basic form by simplesubject-verb-object (SVO) sentences—for example, each of the following simple sentences contains one proposition:

The lawyer rode the bus.

The lawyer saw the bird.

The teacher gave the test.

The doctor read the paper.

Thus, in these examples, there would be two propositions about the lawyer, and one each about the teacher and doctor. The assumption is that the more memory units one has learned about someone or something, the longer it will take to remember them later. With these example sentences, the prediction is that a person should take longer to remember propositions about the lawyer than those about the teacher or doctor. Psychological researchers have tested the hypothesis that a proposition is a memory unit by first having students memorize varying numbers of SVO propositions, then observing how long it takes the students to recognize each of the propositions on a later memory test. The research studies reported here use this methodology.

Your job is to examine these studies and the reported results, then make what conclusions you can from your analyses of the results. In trying to make sense of these results, it is important that you try various ways of organizing, presenting and summarizing the observations until you find a way that provides insight into what is really going on. Some background on related theories and studies is included in the following ***Background Readings*** section to help you in interpreting the results. Write a report describing your analyses, your conclusions and your line of reasoning for those conclusions. What research question(s) would follow most naturally as the next in this line of research and why?

Background Readings

Idea Units in Philosophy

For thousands of years, philosophers have pondered what an idea is and how people combine ideas to infer what is true and what is not. Today, the proposition is the most widely accepted formulation of what an idea is. Basically, a proposition is a relation and the set of entities that the relation interrelates. Consider the following examples:

> The worker went home.
>
> The judge gave the book to the clerk.
>
> The building is tall.

In the first example, *went* is the relation and it relates the entities of *worker* and *home*; in the second example, *gave* is the relation and it relates the entities of *judge*, *book* and *clerk*; and, in the third example, *is* is the relation and it relates the entities of *building* and *tall.* While these simple example sentences contain one proposition (or idea), most actual sentences contain more than one and the concept of proposition allows us to analyze a sentence into the propositions or ideas that it contains. For example, consider the sentence:

> The old man climbed the steep hill.

The main proposition here is

> The man climbed the hill.

but the sentence also contains these other propositions:

> The man is old.
>
> The hill is steep.

In the original sentence, these *is* relations were implicit rather than explicitly stated.

Philosophers have been particularly concerned with how the truth or falsity of multiproposition sentences can be inferred from the truth or falsity of their component propositions and the kinds of connecting words used to combine them. For example, the compound sentence

> The city is big and the building is tall.

is composed of two propositions (*city is big*, *building is tall*) connected by *and*. Philosophers have concluded that the logic of *and* as a connective term is such that the example compound sentence would be true only if both *the city is big* is true and *the building is tall* is true. For another example, the compound sentence

> The city is big or the building is tall.

is different. This sentence uses *or* as the connecting term and the logic of *or* as a connective term is such that this example compound sentence would be true if at least one of the propositions *the city is big* or *the building is tall* is true.

Memory Units in Psychology

Some psychologists have adopted the formulation of ideas as propositions from philosophy, but used it in a somewhat different way. Specifically, psychologists are concerned with ways of measuring how much people remember from something they have studied and some psychologists have hypothesized that the proposition is a good way to measure the number of memory units. A related important issue for psychology is the form in which information gets stored in memory. This is the question of how information is represented in memory.

One psychological theory has it that information is represented in memory as networks of linked propositions. These networks are composed of nodes (usually diagrammed as ovals) and links (usually diagrammed as arrows) with the entities of the propositions being labels on the nodes and the relations of the propositions being labels on the links. For example if someone has learned the following statements:

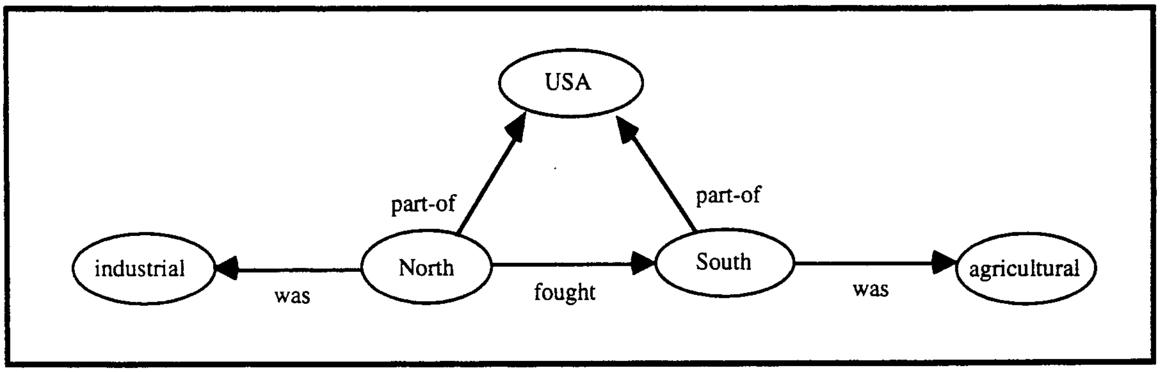
The North fought the South.

The North was industrial.

The South was agricultural.

The North and South were both parts of the USA.

then the corresponding propositional network would be:



Notice that the relations (*fought, part-of, was*) from the propositions label the links connecting the entities (*North, South, USA, industrial, agricultural*) labeling the nodes in this diagram of the propositional network. With a network of propositions like this in memory, the theory claims that if asked a question like

Did the North fight the South?

then the memory search would begin at the *North* node, then search for a *fight* (or *fought*) link and check to see if *South* is the label on the node at the other end of the link. Since *South* is the node, then the answer to the questions is "Yes." (If the node label had been something else — say *West* — then the answer would have been "No.") If the question had been

What is the North part of?

then the memory search would again begin at the *North* node and proceed down the *part-of* link to retrieve the label on the node at the other end and give it as the answer — "USA." In ways such as these, the propositional-network theory of memory claims people store information in memory and then use these memory networks to answer questions.

People as Information Processors

Scientists use analogies to help understand new phenomena by analogy with an area that is more familiar and better understood. For example, when first exploring the atom, scientists used an analogy between it and the solar system — since the solar system was better understood at that time. In this analogy, the nucleus of the atom played the role of the sun in the solar system, and the electrons of the atom played the roles of the planets orbiting around the sun in the solar system. Similarly, psychologists have used many analogies over the years to help understand people better. Since people are very complicated, the natural tendency has been for psychologists to think about people in terms of the most complicated machine around at any given time. Thus, starting in the 1950s with the arrival of the computer as the most complicated machine, some psychologists started thinking of people as processors of information analogous to computers.

From the information processing perspective, human thinking becomes analogous to a computer program and hence can be characterized as a series of stages such as those that would appear in a computer program. In general, the functioning of a computer program can be described as a series of processing stages. For example, the function of a database program could be described in three general processing stages as follows:

1. Read and analyze query.
2. Match parts of query against database.
3. Output results.

Note that the amount of time each of these processing stages takes is affected by different factors: Stage 1 is affected by how complicated the query is, whereas Stage 2 is affected by how many records there are in the database, and Stage 3 is affected by how many matches are found between the query and database. Similarly, information-processing psychologists describe people's performance on a task in terms of processing stages, then look for evidence for these stages by finding different factors that affect the time to accomplish each stage. For a simple example, if the task is to hold a list of a few words in memory and then be immediately tested with a word that may or may not be a member of the list, then the information-processing psychologist might divide the task into the following three stages:

1. Process the test item into the same form as the memory items.
2. Search the memory items looking for a match to the test item.
3. Output the answer "Yes" for match or "No" otherwise.

Evidence for this stage analysis would come from finding that in giving the test item in a different form than the memory items increases the time to respond (affecting Stage 1), from finding that the response time increased with the number of memory items on the list (Stage 2), and from finding that the response time increased the complexity of the output required (Stage 3). For example, if the memory items were the list of words *bus, desk, cat*, then the test item *CAT* would take longer to respond to than the test item *cat* (because *CAT* requires conversion to small letters), and the list of words *bus, coat, desk, apple, cat* would take longer than the earlier list because it has five words instead of only three.

The Studies

In all three of these studies, the psychological researchers select six students and have them memorize the following list of Subject-Verb-Object propositions:

Students 1 and 2 memorized:

The lawyer rode the bus.
The teacher gave the test.
The doctor read the paper.
The mechanic washed the clothes.
The author broke the bottle.
The actor ate the candy.
The lawyer saw the bird.
The mechanic went to church.
The teacher played baseball.
The author kicked the chair.
The lawyer closed the door.
The teacher cut the grass.

Students 3 and 4 memorized:

The actor cut the grass.
The teacher rode the bus.
The author read the paper.
The doctor washed the clothes.
The lawyer ate the candy.
The doctor closed the door.
The mechanic played baseball.
The teacher broke the bottle.
The actor saw the bird.
The doctor went to church.
The lawyer gave the test.
The actor kicked the chair.

Students 5 and 6 memorized:

The mechanic gave the test.
The author cut the grass.
The doctor went to church.
The lawyer read the paper.

The author washed the clothes.

The mechanic broke the bottle.

The actor saw the bird.

The author played baseball.

The actor closed the door.

The teacher ate the candy.

The doctor kicked the chair.

The mechanic rode the bus.

First Study

In the first study, the next day the researcher tested the students by presenting them with one of these propositions at a time on a computer screen, and the students would hit keys to indicate "yes" or "no" about whether they had memorized that proposition the day before. The computer then recorded how long it took the students to respond with an answer. The tables to follow show some of the results for sentences where the students correctly answered that they had been learned the day before (the response times are given in seconds):

Students 1 and 2

Test Sentence	S #1 Times	S #2 Times
The lawyer saw the bird.	1.495	1.509
The mechanic washed the clothes.	1.312	1.292
The doctor read the paper.	1.114	1.091
The teacher cut the grass.	1.515	1.487
The author broke the bottle.	1.315	1.285
The actor ate the candy.	1.097	1.103

Students 3 and 4

Test Sentence	S #3 Times	S# 4 Times
The lawyer ate the candy.	1.304	1.286
The author read the paper.	1.097	1.105
The teacher broke the bottle.	1.296	1.309
The mechanic played baseball.	1.106	1.093
The actor cut the grass.	1.508	1.494
The doctor washed the clothes.	1.497	1.502

Students 5 and 6

Test Sentence

	S #5 Times	S# 6 Times
The teacher ate the candy.	1.097	1.105
The author cut the grass.	1.515	1.486
The lawyer read the paper.	1.110	1.087
The mechanic broke the bottle.	1.495	1.503
The actor gave the test.	1.290	1.315
The doctor went to church.	1.310	1.289

Second Study

In this study, the researcher had a different set of six students memorize the same set of sentences that were memorized in the First Study, except that now the students were tested with the passive voice version (Object-Verb-Subject) of the sentences instead of the active voice (SVO) version that they had memorized. They were told to respond by hitting the "yes" key if the test sentence was the passive voice version of one of the sentences they memorized, but to respond with the "no" key otherwise. The following were the response times for the passive voice test sentences in the study:

Students 1 and 2

Test Sentence	S #1 Times	S #2 Times
The bird was seen by the lawyer.	1.816	1.785
The clothes were washed by the mechanic.	1.590	1.612
The paper was read by the doctor.	1.411	1.409
The grass was cut by the teacher.	1.795	1.807
The bottle was broken by the author.	1.601	1.598
The candy was eaten by the actor.	1.399	1.400

Students 3 and 4

Test Sentence	S #3 Times	S #4 Times
The candy was eaten by the lawyer.	1.604	1.598
The paper was read by the author.	1.405	1.400
The bottle was broken by the teacher.	1.596	1.608
Baseball was played by the mechanic.	1.397	1.402
The grass was cut by the actor.	1.806	1.793
The clothes were washed by the doctor.	1.789	1.809

Third Study

In this study, the researcher had yet another set of six students memorize the same set of sentences that were memorized in the First Study, except that now the students were tested with paraphrases of the sentences memorized. They were told to respond "yes" if the test sentence had essentially the same meaning as a memorized sentence, but to respond "no" otherwise. For example, if one of the memorized sentences was

The professor wrote the paper.

Therefore, an acceptable test sentence with the same basic meaning would be

The professor wrote the article.

The following were the response times for the same-meaning test sentences in this study:

Students 1 and 2

Test Sentence	S #1 Times	S# 2 Times
The lawyer saw the fowl.	2.106	2.095
The mechanic cleaned the clothes.	1.694	1.702
The doctor read the news.	1.305	1.298
The teacher cut the lawn.	2.113	2.090
The author shattered the bottle.	1.713	1.690
The actor ate the sweets.	1.292	1.307

Students 3 and 4

Test Sentence	S #3 Times	S #4 Times
The lawyer ate the sweets.	1.696	1:711
The author read the news.	1.307	1.289
The teacher shattered the bottle.	1.712	1.691
The mechanic played hardball.	1.304	1.297
The actor cut the lawn.	2.093	2.101
The doctor cleaned the clothes.	2.108	2.090

Students 5 and 6

Test Sentence	S #5 Times	S #6 Times
The teacher ate the sweets.	1.297	1.305
The author cut the lawn.	2.119	2.082
The lawyer read the news.	1.310	1.287
The mechanic shattered the bottle.	2.089	2.110
The actor gave the exam.	1.690	1.703
The doctor attended church.	1.710	1.697

Appendix B.2: *Galileo* Scoring Scheme

I. *Pattern Recognition* (Total 20 Points)	
A) Study One (Maximum 4 points)	
1) Positive relationship between subject and response time	____/2
2) Reported means/ratios	____/1
3) Alternative patterns	____/1
Total for Study One	____/4
B) Study Two (Maximum 7 points)	
1) Positive relationship between number of propositions and response time	____/2
2) Takes longer than Study One	____/2
3) Positive relationship between subject and response time	____/1
4) Reported means/ratios	____/1
5) Alternative patterns	____/1
Total for Study Two	____/7
C) Study Three (Maximum 9 points)	
1) Positive relationship between the number of propositions and response time	____/2
2) Takes longer thanStudy One	____/1
3) Takes longer than Study Two	____/1
4) Reported means/ratios	____/1
5) Steeper climb than other two cases	____/2
6) Alternative patterns	____/1
7) Positive relationship between subject and response time	____/1
Total for Study Three	____/9
II. *Explanation and Argumentation* (Maximum 30 Points)	
A) Study One (Maximum 6 points)	
1) Contextual interpretation	____/1
2) Propositions explanation	____/2
3) Nodes & links explanation	____/2
4) Hypothesis testings	____/1
Total for Study One	____/6

B) Study Two (Maximum 12 points)

1) Stage of transforming from passive to active takes time ____/4
2) Match against database takes time ____/4
3) Nodes/links/propositions ____/2
4) Context explanation ____/1
5) Hypothesis testing ____/1

Total for Study Two ____/12

C) Study Three (Maximum 12 points)

1) Different word/same meaning increases search time ____/4
2) Match against database increases time ____/4
3) Nodes/links/propositions explanation ____/2
4) Context explanation ____/1
5) Hypothesis testing ____/1

Total for Study Three ____/12

D) Extra Credit for Recommendations for Future Studies

Total for Extra Credit ____/?

III Data Representation (Maximum 10 Points)

A) Ideal graphing solutions (Maximum 5 points)

1) Graph Study One ____/1
2) Graph Study Two vs. Study One ____/2
3) Graph Study Two vs. Study Three ____/3
4) Graph Study Three vs. Study One ____/4
5) Graph overall trend ____/5

Total Graphing Solutions ____/5

B) Representations for proposition/nodes/links (Maximum 5 points)

1) Fan effect ____/2
2) Spreadsheet ____/2
   (Partial credit for rejected hyp. testing)
3) Flowchart ____/1

Total Graphing Solutions ____/5

CUMULATIVE TOTALS (Maximum 60+) ____/

Appendix C: Data Representation

Fig. 1 Graph of Response Time Against Number of Propositions per Subject

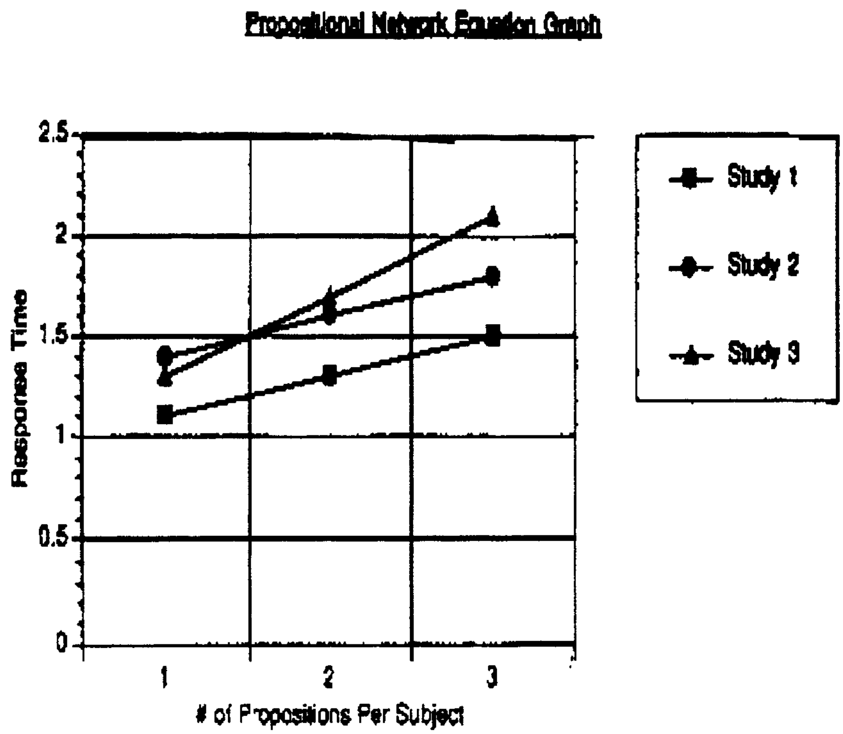


Fig. 1a
Flowchart of Information Processing Model

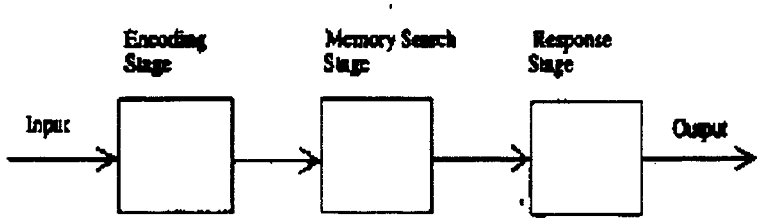


Fig. 2 Galileo Worksheet

Study 1	3x	2x	1x
1 2 avg	1.505	1.301	1.10125
3 4 avg	1.50025	1.29875	1.10025
5 6 avg	1.49875	1.301	1.09875
Study 2	3x	2x	1x
1 2 avg	1.80075	1.30025	1.404725
3 4 avg	1.79925	1.4015	1.401
5 6 avg	1.802	1.50025	1.40125
Study 3	3x	2x	1x
1 2 avg	2.101	1.69975	1.3005
2 3 avg	2.098	1.7025	1.29925
5 6 avg	2.1	1.7	1.29875

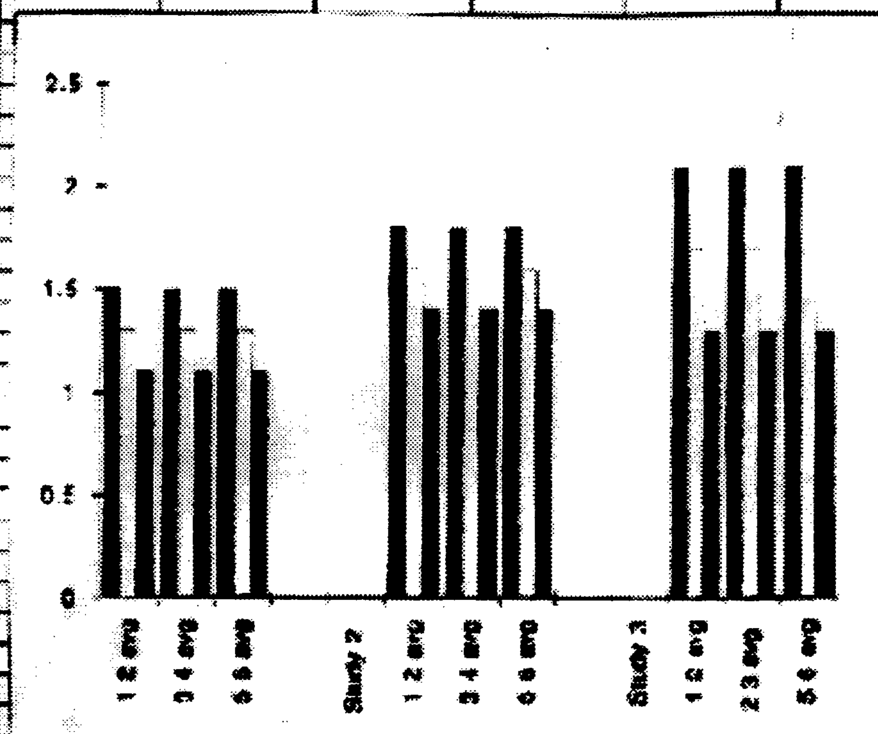
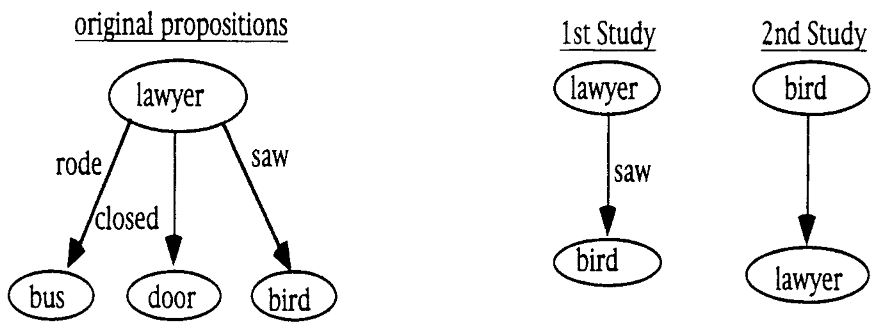
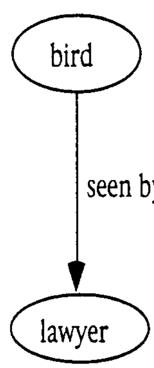


Fig 3 A Propositional Network Constructed by a *Galileo* Student



Here there are three mental patterns that must be examined.

team



Here there is only one; however, the conversion of the link from "saw" to "seen by" must take more time because the response times are longer.

2) Qualitative Evaluations of Process and Product

Introduction

As in the past year, we asked outside evaluators to do qualitative assessments of projects, focusing on classroom process and on student work in the context of that process. We sought out specialists in the relevant content areas to begin with, but also people with an interest in and commitment to education, people who might be interested in the possibilities of the new technology, not for its own sake, but for reform. In two cases, we brought back evaluators from the previous year, asking them to focus particularly on changes they might observe, paying special attention to the problems and opportunities created by the increased interest and activity in the school as a whole. In the other cases, we engaged new people, some with national reputations in their fields.

The process of evaluation varied according to the circumstances surrounding each project, of course, but all the evaluators were asked, at a minimum:

- to observe project activity in the classroom for several sessions;
- to meet privately with groups of students to explore the project and their work in it from their point of view;
- to talk at length with the faculty and staff responsible for project development.

Evaluators were also given samples of student work to consider. We expected a report of ten to twelve pages, plus appendices where appropriate. The main body of the report was to consist of a comparative evaluation of classroom process, student achievement, and the role of the teacher. Evaluators were asked to concentrate, above all, *on the ways in which the new technologies have been deployed in the context of the educational goals of the project.* That is, to evaluate the education, not the technology. We also asked for whatever recommendations the evaluators could make for future development and assessment.

* * *

Dalton School—Review of Primary School Technology Program: Dorothy Bennett and Jan Hawkins, Center for Children and Technology, Bank Street College of Education

Overview of the Review Process

The contents of this report are based upon a two and a half-day review of the Dalton School's First Program Technology Lab. Director, Jan Hawkins, and senior research associate, Dorothy Bennett, from the Center for Children and Technology, met with Karen Bass, Technology Coordinator for the First Program, and Design Associates, Ellen Levenson and Wendy Weisner, to interview them about the process of preparing the First Program's technology integration efforts and issues concerning staff development and ongoing project activities. In addition, we observed several K-3 classes at work in the lab over two days. On these days, we observed "Relatives Day" in which children presented their final projects to visiting relatives. In addition to project presentations, we observed regular lab classes in which students were working on class projects.

> The central first floor location was a wise choice for this lab space—rather than a more isolated corner of the building—because teachers, children, and parents serendipitously observed the active technology-enhanced work simply by walking by or through the room.

Observations focused on the nature of interactions between students and staff, the degree of student engagement witnessed, and the students' projects themselves. Discussions with members of the lab design team took place to obtain a fuller understanding of the day-to-day activities within the lab and how it is used by both staff and students.

To gain a sense of how technology was used, students' project presentations on Relatives Day were videotaped and used for background data in conducting this review. The design team also supplied a portfolio of projects K-3 students produced over the course of this past year.

Given the limited time we spent at the school, this report aims to provide a narrative impression of the accomplishments of the First Program technology effort and suggests next steps that can be taken to continue the growth and development of the staff's work. Our impressions and interpretations are grounded in previous research and experience working with a wide array of schools that are attempting to integrate technologies into classrooms.

The Broader Context of Technology Integration in Schools

Technology is important for furthering efforts to create constructivist classroom environments in which children grapple with complex problems hands-on, synthesizing and using a wide array of information and materials that lead to meaningful and memorable learning experiences. Computer software tools, such as word processing and graphics programs, can help organize and structure complex tasks for students. Multimedia applications enable students to create attractive, professional-looking products of their own design, which can be easily shared and revised. The public nature of computer work can help support collaboration, discussion, and reflection.

Yet as much of our research at the Center for Children and Technology has indicated, the unique features of technology alone cannot accomplish these ends. Rather, it is the way in which technology's capacities are put to use in human environments that shape their impact. Through collaborative partnerships with a wide array of different schools over the past 12 years, we have studied different model configurations of successful technology use in schools. We refer to these studies as design experiments.

> In much of our outreach work in schools, we have rarely encountered such a well-planned effort to train and support teachers and it seems that the New Lab has developed a model that would be useful to other school settings.

We have identified a number of key issues that must be considered in developing technology-enhanced schools: how space and technology resources are set up, the key people involved, how staff development is handled, if at all, and how technology itself is used in relation to the curriculum. Through this lens, we have found that in almost all cases, successful programs require considerable and allotted time for staff development, a rich project-based curriculum, time for teachers and students to experiment with different applications, reflection on the part of the staff, and collaboration between technology experts and teachers. In the best cases, technology becomes an integral tool in the work that students do, expanding the curriculum. In addition, computer use is most successful when tasks are open-ended and complex enough to invite students to research, revise, reflect, and create at their own pace.

According to a national survey conducted by our Center on accomplished teachers who have successfully integrated technology into the daily life of their classrooms (Sheingold & Hadley, 1990), it takes teachers up to five to six years to master computer based practices and approaches in the manner described. It is worth keeping this context in mind when looking at the efforts of the First Program.

Planning for Technology in the First Program: A Look at First Steps

Perhaps the first challenge schools face in attempting to integrate technology is deciding on what kind of setup can benefit the maximum number of students and teachers. In addition to providing access to the computers themselves, staff and students have to become comfortable users of and thinkers about technology as a resource for their work in order for it to become an integral part of teaching and learning.

In discussions with the design team, it was clear that a great deal of preparation went into thinking through how to reach out to teachers and students within the school. In the first year of the Dalton Technology Plan, ten computers were placed in classroom settings so that each house had at least one computer. In the second year, a lab with ten computers with child-oriented graphics programs, word processing and printers was set up on the first floor for teachers and students to use on an ongoing basis. The central first floor location was a wise choice for this lab space—rather than a more isolated corner of the building—because teachers, children, and parents serendipitously observed the active technology-enhanced work simply by walking by or through the room.

The general approach to integrating the technology resources into the school seemed to be quite compatible with the overall philosophy of the school, and where the school wants to go. The emphasis on expression and production with the technology (e.g. writing, graphics, HyperCard, and now communications) reflects a primary emphasis on tools of expression. The emphasis on the support of the design team to help teachers advance, enhance and refine their curricula with technology resources fits well with the overall approach of the school to teacher-generated learning environments. We have found that to be successful and sustained, the approach to technology integration must reflect the broader philosophy and values of a school, as we observed here.

Thus, rather than leave teachers (several with little computer experience) on their own to figure out how to make use of their newly arrived machines, the design team spent 10 weeks with teachers and students in their respective classrooms to introduce them to computer skills and techniques and to brainstorm how their curricula could develop in a multimedia environment. To facilitate this, the design team developed easy-to-read "MacIntosh Basics" handouts for teachers and students and all were introduced to word processing programs and graphics programs. Throughout this training period, the design team believed that it was critically important to learn about the kinds of curricular projects teachers were engaging their students in, which seemed to provide a good base for collaboration among the team and the teachers.

This thoughtful and thorough approach to staff development is often lacking in schools with the best intentions and is crucial to sustained and meaningful use of technology. It seemed evident in both observations and discussions that design team members worked collaboratively with staff from the ground up to enhance existing curricular projects in their classes or to develop new projects that interested or intrigued the teachers. In much of our outreach work in schools, we have rarely encountered such a well-planned effort to train and support teachers and it seems that the New Lab has developed a model that would be useful to other school settings.

To get a better understanding of how collaboration took place between the design team and the teachers, we asked the team how often teachers made use of the lab and how the collaboration process evolved. They reported that several interested teachers initially came to them with their project ideas during scheduled planning

> What was particularly impressive about this effort was the way in which the team adapted the technology to the teachers' aims and purposes, providing unobtrusive yet powerfully creative contexts for them to extend their teaching. We also noted the flexibility and effort with which the team approached this complex social task (e.g. one teacher had already covered the rain forest, so the technical and curriculum supports were adapted so that she could do a parallel project about sea life), and the reflective and revisionary attitude with which they analyzed the project.

times to learn about which computer applications could help their efforts. As projects got under way with these teachers, word of mouth drew in other teachers to try out similar projects. While the lab always had an open-door policy, there is now a public sign up sheet for computer time to accommodate the increase in computer projects in the First Program.

While observing students at work in the lab, it was interesting to note that teachers were often present with their students. The design team helped introduce new applications to students, and teachers would coach students on their projects or would observe what the students were doing. In this way, the lab seemed like an extended workshop for teachers and students rather than a haven where technical experts manage the technology.

Overall, the staff development efforts of the design team seemed to pay off. While some of our studies have indicated that it usually takes up to five years for teachers to successfully integrate technology into the curriculum, we were surprised to learn that the lab program had just been set up this year. The degree of students' engagement and proficiency on the computers is an indication that the time spent bringing staff and students up to speed was well worth the effort.

The Uses of Technology: Meeting the Needs of the Primary Grades

Early childhood and elementary school classes are multimedia environments to start with. From blocks, drawing, to hands-on explorations of archaeology, students work with a variety of media and tools to investigate their neighborhoods and the outside world. At Dalton, technology serves as a natural extension of classroom resources. But little systematic research-based evidence has yet accumulated about developmentally appropriate uses of technology at the early elementary school level.

Early childhood presents different learning goals than the upper years. Students are developing fine motor skills and emerging literacy skills. It is an intense period of fact-finding and making sense of the curious, exciting world around them. According to developmental psychologist Dorothy Cohen (1972), teacher-led activities for kindergarten and the early years should be geared to foster thinking processes and build upon play. Keeping within a constructivist perspective that appears to be central to curricular efforts at Dalton, teachers are challenged to provide activities and projects that help students build and create their knowledge in a hands-on, experiential manner to achieve these ends.

The very first challenge the design team faced was teaching young students to navigate through the MacIntosh environment. Not unlike their work with the teachers, at the start of the program, design team members spent a good deal of time teaching young students about the basics: how to turn the computer on, the parts of the computer, how to use a mouse, creating folders and files, how windows work, and how to format disks. During observations, it was surprising to see how savvy the children were. They opened applications with relative ease and consulted with each other and the design team for help when needed. Girls as well as boys were engaged and working at all times, which according to several research studies, does not necessarily happen automatically. The teachers also reported being surprised at the skill and confidence demonstrated quite quickly by many of their students in, for instance, control of the mouse, and finding their way around reasonably complex software programs.

The Nature of Projects in the First Program

The First Program design team and teachers have found interesting ways to integrate technology into the primary grades curriculum. A range of applications was witnessed, from word processing to graphic programs as well as a HyperCard template to help organize the students' research on a simulated archaeological dig. All activities were grounded in ongoing projects teachers had developed in the classroom and appeared to pose interesting opportunities for students to reflect on and learn from the work they were doing.

The projects we witnessed or heard about seem to fall into three types: projects or activities that the design team helped individual teachers to develop or incorporate into their curriculum; interdisciplinary projects that required coordinated activity among a group of classroom teachers, specialist teachers, and the design team; amd technology-rich projects that are supported by outside technology specialists. A representative sample of projects is reviewed below, informed by observations of students presenting their work on Relatives Day and discussions with Karen Bass, Ellen Levenson, Wendy Weisner, and respective teachers.

1. Classroom Projects: Kid Pix *Writing, Reading, and Researching*

Kid Pix is an engaging, easy-to-use graphics program that provides a palette of icons, letters, and drawing tools for young children to create interesting graphic displays with sound effects. *Kid Pix* and *Kid Pix* slide show were used by students in a variety of ways to create and illustrate stories, books, and research books on other interesting mathematical or scientific information that they gather in the classroom. According to Karen Bass, the introduction of *Kid Pix* seemed a natural way to make the book-making process and student research more student-centered. Prior to the arrival of the computers, teachers often gathered students' drawings and writing samples and assembled them in a book; with *Kid Pix*, the students were integrating the pieces themselves on the screen. Drawings or photographs were scanned in by teachers, while students elaborated on them by writing or by adding icons and colors to images. In a research project on zoo animals, students created a map of the zoo, wrote about their favorite animal and teachers scanned in the students' own drawings, and photographs of the actual animals. Another kindergarten class used the icons in *Kid Pix* to create number sets (e.g., 46 fish), and added creative sayings and sound effects to celebrate the first 100 days of the year. In cases where children did not write, the team recorded the students' narrative over a picture and typed in the words for the student to refer back to whenever they wanted.

2. Interdisciplinary Projects: The Rainforest Project

This complex and interesting project involved several classroom teachers and the science specialist as well as the design team. An extensive planning process enabled the team to create a rich and apparently powerful learning experience for students in which each student created a multimedia project that presented his/her understanding of rain forest animal protection in graphics, audio and written text. The technology was appropriately and creatively incorporated specifically in relation to learning goals defined by the team. For example, the project began with a visit to the zoo in which children were encouraged to closely observe individual animals. On such visits, students of this young age often must delay recording/reporting of their observations until they return to school. The science specialist saw audio technology as an opportunity for students to record what they saw while they were actually watching the animal. A HyperCard "shell" was designed and developed by the team that enabled the students to draw their animal in *Kid Pix*, add their own audio-recorded observations, and write their findings about the animal from library research. This combination of media allowed students to create impressive projects. The design team also provided the purpose and support for teams of teachers to work together in some new ways.

What was particularly impressive about this effort was the way in which the team adapted the technology to the teachers' aims and purposes, providing unobtrusive yet powerfully creative contexts for them to extend their teaching. We also noted the flexibility and effort with which the team approached this complex social task (e.g., one teacher had already covered the rain forest, so the technical and curriculum supports were adapted so that she could do a parallel project about sea life), and the reflective and revisionary attitude with which they analyzed the project. (We witnessed a discussion in which the team analyzed in some detail how they needed to tinker with the approach to make it work better the next time.)

3. *Specialized Projects: Don Nix and Multimedia Projects*

Don Nix has been working with classes in the First Program to create impressive multimedia projects that grow out of the interests and needs of the students and teachers. He is an extremely valuable resource, who directly provides some wonderful learning opportunities for students; he also provides support for teachers to think about how multimedia creation can be a powerful part of the curriculum. The project that we observed was a completed multimedia project in which a class of students had created an interactive videodisk about families. The teachers and students had planned the disk design and segments, created and produced the "dramas" and dilemmas that appear on the disk, and helped in the critique and editing of the video segments. Don provided the technical support and know-how for the design, creation and execution process. He is currently providing a similar experience to another class about an historical period they are studying.

4. HyperCard *as a Research Tool: Inwood Park Project*

This year, 3rd graders worked on a simulated dig of Inwood Park developed by another kind of specialist—an in-house archaeologist at Dalton. Artifacts were arranged in four levels of dirt so as to provide clues to certain historical periods (the deeper one went down, the earlier the period). Students excavated artifacts that ranged from typewriters to a Viking's helmet. Once excavated, each student was required to identify the artifact's salient characteristics (weight, texture, and the materials it was made of) and the level of the dirt and location it was found in. Using this information along with photographs of their artifacts, students had to conduct research to identify the historical period that the artifact belonged to and how it was used.

In carrying out such a project with third graders, teachers had to find a way for students to integrate and reflect on the information they collectively gathered in order to see trends. To achieve this end, a member of the design team developed a HyperCard template which allows students to organize information about the artifacts that they had found. Each student was required to enter her/his data into the program, including a write up about the historical significance of the artifact. Scanned images of the artifacts were included along with all other pertinent information collected. After data entry was completed, students could navigate through the stack according to the level in which the artifact was found as well as look up historical information about the object and related artifacts. During students' presentations to their relatives, it was clear that several students were comfortable navigating through the stack. We witnessed them making connections between the different data that they and their classmates had entered ("This is Ben's artifact."). According to the design team, many students were excited to see all of the work they had done as a group gathered in this way.

The strength of all of these projects is the opportunity the technology gives students to reflect on what they and their classmates have done. In addition, these types of projects appear to facilitate literacy skills among young children who are at different stages or who have different learning styles. As students proudly showed parents, friends, aunts and uncles the storybooks they had created using *Kid Pix* and the rain forest multimedia projects, they pointed to words on the screen, and to their pictures, and recited their stories and texts aloud. Both teachers and members of the design team informed us that several of the students are able to quickly identify their own work by images or sounds and often remember verbatim what it is that is written on the cards even though they are not reading yet. Hearing their own narration over images and seeing text on the screen perhaps helps young students make connections between words and their meaning.

According to some members of the design team, the letters palette in *Kid Pix* also seems to help some students who have trouble recognizing letters. Every time a child picks a letter from the palette, the computer announces the name of the letter in a childlike voice. The design team and some teachers reported that this feature was particularly helpful to students who had trouble spelling.

Overall, nearly all of the students we observed were extremely facile in using the computers and eager to teach their elders during Relatives Day. While teaching his uncle how to use the icons, a first grader created a new story about how dinosaurs have taken over Manhattan. Relatives Day in particular seems to promote students' confidence and self-esteem since in many cases the students knew much more than their relatives did about computers. Parents and other relatives were also drawn into the process and reacted very positively to the kinds of work the children were doing. The public presentation of final products is one of the key variables we have identified in our research concerning successful integration of technology into schools: it is important for students to display complex work to audiences of peers and adults.

5. *Observations of Regular Lab Activities:* Bank Street Writer

As was mentioned previously in our discussion of the training efforts of the design team, all students were taught to use simple word processing programs. In the classes that we observed, third graders were writing stories using the easy-to-use *Bank Street Writer* program. A great deal of collaboration between students seemed to take place in the lab, where students consulted each other for the "right word" to make their stories come alive or to brainstorm ideas for new plotlines.

In the time we had to observe students, we could not determine with scientific precision what effects the computers have had on students' writing abilities. A more extensive evaluation of students' work over time would be required to assess learning outcomes. But our conversations with students and the design team suggest that word processing and access to other graphics tools seem to free students up to write. A visiting kindergarten teacher pointed out how surprised she was by the amount of writing that one of the third graders present in the lab was doing. When she had him in the first grade, she felt the student had very poor fine motor skills and hated to write anything. She reported that the computer perhaps gave this student what he needed to get down his thoughts and overcome his difficulties.

Recommendations

1. *Creating Models for Technology Integration in Early Childhood Programs*

Relatively little research has been done on technology integration in the early elementary grades. The First Program design team and the various collaborating teachers have taken many valuable steps in setting up an exciting model that is responsive to the needs of students and teachers. One big challenge is figuring out what applications are developmentally appropriate for the children. While simulations and other computer applications may provide interesting opportunities that could extend curricular activities, it is unclear how complex technology applications should be in the early grades when students are still learning about computers. Observations and discussions with the design team have indicated that graphic applications like *Kid Pix* may play a role in facilitating students' literacy skills. Further investigation into how emerging literacy skills are enhanced as students engage in future projects of this nature would be worthwhile for the team to explore. Findings from such an investigation would be extremely valuable to others in elementary settings.

> To assure that efforts continue to grow within the First Program, it appears that the school may need to take a more global look at the continuity of students' experiences with technology as they move through the grades....There also is a concern about bridging gaps between technology efforts of the First Program and efforts at the upper school on 89th Street, so that students can easily make a transition from one place to another programmatically.

Maintaining and extending the level of the design team's time for experimentation seems necessary for the program to continue to grow and for them to explore the options available to them. In many cases, the New Lab has begun to define effective use of technology in the primary grades at Dalton. Therefore some time for the design team to reflect on the value of different projects and applications would undoubtedly be helpful to the program itself and as a model for other early elementary settings. There is a great need for strong school-based models of technology in the early grades for the larger educational community.

The design team's hands-on collaborations with teachers also seem necessary to maintain, as they appear to augment the kinds of projects that are meaningful to teachers and students. As the latter become more familiar with technology, there will be many new projects and applications of technology that have not been tried—several interesting ideas that teachers had for new applications that could be developed by the team were mentioned during our visits. This is not to say that technology should necessarily get bigger and glitzier; the team has to continue to explore technological options that meet the developmental needs of the children.

2. Assuring Continuity in Student Experiences WithTechnology

To assure that efforts continue to grow within the First Program, it appears that the school may need to take a more global look at the continuity of students' experiences with technology as they move through the grades. There is a concern among the design team about the amount of resources available to lower and upper grades in the First Program. Once students reach the fourth grade, they no longer have access to MacIntosh computers. In this case, many of the skills and experiences younger students have had may fail to carry over later on. There also is a concern about bridging gaps between technology efforts of the First Program and efforts at the upper school on 89th Street, so that students can easily make a transition from one place to another programmatically.

3. Space and Time for Design Team To Experiment With New Technologies

Some of the most powerful ways of integrating technology in the First Program involve the creation of new or adaptation of existing software by the design team. The staff currently does this design and programming work in the lab that is used by students, with frequent interruptions and without the continued access to computers that is needed for this kind of development work. If curriculum creation and adaptation are to be a continued centerpiece of the technology program, a separate space and some dedicated development machines would be needed for staff and teachers.

In addition, several teachers and staff expressed a specific interest in including video production more substantially in the First Program. Don Nix seconded this interest. There are currently no video editing facilities in the building, and there is not sufficient professional support to integrate video substantially. Equipment and professional support needs for this particular technology should be carefully considered.

4. *Need for Additional Technical Support*

In moving forward, and as additional technologies become available to the New Lab, it appears that the design team will also need additional technical support in meeting the needs of the First Program. Without additional support, it would be difficult for the team to provide the same kind of timely training and staff development that has been successful up to this point. It also appears that the First Program's design team can use more assistance and ongoing communication with 89th Street. As the number of teachers who become involved increases, there also needs to be some level of time set aside for teacher collaboration to take place on a regular basis so that technology efforts could be sustained and extended.

Special consideration needs to be given to the introduction and maintenance of the network which will be extended to the First Program in the coming year. This is a very exciting project, since it represents a pioneering effort to bring advanced communications technology to the early grades. It thus is fraught with many challenges. In our research with teachers and telecommunications, we have found that working with telecommunications can be a frustrating experience even for computer-literate adults. Introduction of the technical aspects and the *purposes* of this technology need to be fully planned. In addition, our experience indicates that a network designed to serve an entire institution of 400 students and 50 adults will require substantial in-house technical support to keep it running smoothly. There is concern about—and great interest in—whether and how very young students will learn to navigate the software and in defining interesting purposes for its use. At the beginning, it may be most promising to concentrate on involving teachers through functions directly designed for their professional growth, rather than at first emphasizing student use. For example, teachers appeared eager to use the network to communicate with colleagues within the school for things like planning interdisciplinary projects, creating a common database about what books were in each classroom and who borrowed them, and communicating with teachers at the 89th Street building, perhaps to address the issues of continuity that are of concern. With respect to projects involving students, the teachers were most enthusiastic about projects that enabled the students to communicate with others—like regular relationships with older students at 89th Street, or with Don Nix's students at PS 92. A project involving students in the two schools is already being planned.

Finally, collaborative multimedia projects developed with the help of technical consultants like Don Nix make up a resource that is unusual to Dalton and a highly valuable part of the program. While few teachers would be able to quickly gain the expertise provided by Don, they can gain the conceptual understanding about the design and value of such advanced projects. The First Program should consider whether, and how, it may want to extend the kinds of experiences offered within the school by collaborating with specialists in this manner for concentrated periods of time.

In sum, the First Program has done a remarkable job of incorporating technology into the curriculum and life of the school during this first intensive year of the Lab, paying careful attention to harmonious coordination with the school philosophy and professional culture of teachers. The design team has inspired, coordinated, and supported a range of impressive and successful projects. To continue to develop the technology integration efforts in a deep way that will serve as a model for other schools, the next stage requires attention to and decisions about the technical and human support resources that will extend the program to the next level.

References

Cohen, D. (1972). *The Learning Child.* New York: Pantheon Books.

Sheingold, K. & Hadley, M. (1990). *Accomplished Teachers: Integrating technology into classroom practice.* New York: Center for Technology in Education, Bank Street College of Education.

Evaluation of Computers and Writing—Fourth Grade Project: Judith Rae Davis, Assistant Professor of English, Bergen Community College; Adjunct Instructor of English Education, Teachers College, Columbia University

> *The point is that it's not necessary to understand the wonders of technology in order to enjoy them, and this should be as true of computers as it is of cars.*—William Zinsser, *Writing With a Word Processor*, p. 23.

Introduction

Most writers who use word processors for composing their texts agree that the technology facilitates the writing process, since more energy can be devoted to the creation and revision of text, rather than to the recopying or transcribing of existing text. Monica Edinger, a fourth-grade teacher at The Dalton School, asked herself if word processors would help the young writers in her class.

William Zinsser suggests that the technology of the word processor would eliminate the biggest obstacle that young children have in writing: the sheer labor of handwriting.

> Children are natural writers. Their heads are full of imagery and wonder and word-play and free association; their use of language is fresh and unexpected. But their hands are far slower that their thoughts. The act of forming words with a pencil is hard, and the words that they painfully manage to form don't satisfy anybody—not the teacher, who wants them to be more legible and neat, and certainly not the child, who wishes that his words didn't look so childish. A writer at any age deserves a certain integrity for his writing. (p. 110)

Ms. Edinger appears to have had the same suspicions as Zinsser and with the help of The New Laboratory for Teaching and Learning equipped her entire fourth grade class with Tandy laptop portable word processors. I had the opportunity to visit the Dalton School on May 12, 13, and 14, 1993. I observed and interviewed the fourth grade students in Monica Edinger's classroom. I also looked at their written work and spent time talking with their teacher.

The Writing Process Classroom

"Writing is a deeply personal process, full of mystery and surprise. No two people go about it in exactly the same way." (Zinsser, 1986, p. 96) Just as students have their own unique ways of going about writing in their writing workshop, each student in Ms. Edinger's class has designed his or her own way of using the word processor in the context of that workshop.

> During the workshop, some students spoke with each other about their writing. Students frequently looked up from their work and asked a peer about how to spell a word or where to start a new sentence....Two students were having an editing conference—one student gave his Tandy to his friend who read aloud from it and made spelling and other editorial changes by typing them into his friend's document.

At the beginning of the workshop, most of the students went to the cabinet quietly, took out their notebook-sized word processors and writing folders and took them to their desks to begin work. Students were writing memoirs: stories about their heritage, memories from early childhood, and anecdotes passed down through their families. A few students did not work with the Tandys and made book covers for their projects while they talked quietly on the floor. One student sat with the teacher, computer in her lap, pointing to parts of her memoir that needed improvement before printing. Instead of holding the student's paper and a red pen, the teacher took the laptop, like a notebook, and helped the student "cut and paste" a section of her memoir. Several other students waited for conferences. A few students wrote with pencils and paper, waiting to use their word processors for the final copy.

During the workshop, some students spoke with each other about their writing. Students frequently looked up from their work and asked a peer about how to spell a word or where to start a new sentence. One young man's computer made a beeping sound, so he stopped writing, went to the battery charger, took out four batteries for himself, removed the weak batteries from his Tandy, and put them into the charger to replenish them. Two students were having an editing conference—one student gave his Tandy to his friend who read aloud from it and made spelling and other editorial changes by typing them into his friend's document. After an initial quiet time, students were permitted to use the single MacIntosh computer and printer in the room to print the final drafts of their work. While all of this was going on, a preceptor went through the classroom and helped students with editing by explaining rules about spelling and mechanics.

After about forty minutes of writing, the group assembled on the carpet and eagerly waved hands in hopes of being selected to read what had been written that day. Instead of holding a black and white speckled composition notebook, as I might have done in the fourth grade, or a small chalkboard, as my grandmother might have done, these writers read their texts from the 3-inch-by-10-inch screens of their word processors. They had to pause occasionally to scroll their texts so they could finish reading. After reading aloud, the students in the class responded with suggestions for revision or questions about the writing. The author responded orally and took the ideas of his/her peers' ideas into consideration. Revision would occur in the next day's writing workshop.

This ritual is repeated daily as the young writers work on their projects and participate in a variety of activities to foster creativity and revision. I have observed and participated in many writing workshops in the last decade, and I wondered what role, positive or negative, the technology of the word processors might have played in this one.

Evaluation

It is crucial to separate the effects of the technology from the effects of excellent pedagogy and teaching. Since Ms. Edinger's students used the Tandys all year, it is difficult to imagine and impossible to conclude that her students did better with word processors than they would have done without them. Samples of this group's written work are longer, more detailed, and more correct than samples of writing done on comparable projects by students in last year's fourth grade. Any researcher will tell you that this is not a valid comparison, since it is two different populations in two totally different contexts. And even if their written products appear better than students who didn't use word processors, Ms. Edinger's goal with this project was to use the technology to enhance the writing *process*. Care must be taken not to fall into the trap of relying on written *products* to make conclusions about the effectiveness of the students' writing *process*.

How can one find out how the Tandys affected the writing processes of these students? I spent a significant amount of time collecting anecdotal evidence and will suggest later that the teacher engage in formal and ongoing classroom research to follow up this evaluation. I looked for evidence of students' willingness to make changes in their work. Research by Daiute (1983) and McKenzie (1984) suggests that word processors change writers' attitudes toward the task of writing. As Daiute (1983) commented, "Not having to recopy helps writers compose freely, focusing on what they want to say...the ease of revision encourages writers to experiment and to view their writing as dynamic" (p. 139). I was interested in students' affective attitudes about their own handwriting and the use of the word processor. I tried to find out if these young writers wrote or thought differently when they used pen and paper from when they used the technology. I asked them, as I would any writer, what they thought were the problems and benefits of using word processors to write.

A. Problems of the Technology

Students mentioned a few difficulties associated with the word processors, but I observed minimal problems. Keyboarding skills were mentioned by all students. Ms. Edinger attempted to teach keyboarding skills throughout the school year, but was unable to locate materials to do so since the Tandys did not support software. In February, she located an appropriate typing book and engaged students in a "touch typing" program that taught keyboarding skills. Once they learned how to type, students found using the word processor fun and helpful. However, in the beginning of the school year, and before they learned keyboarding skills, many were forced to "hunt and peck." In some cases this was more frustrating than working with a pencil, and students preferred not to use the Tandy. Students who never mastered the keyboarding and for whom handwriting was easy tended *not* to use the Tandy even when I visited in May. All but three students used the Tandy for composing, and every student used the Tandy to type his or her work for classroom publication.

The recharging of batteries and the need to change them frequently were drawbacks expressed by many students. Although files were not lost when batteries grew weak, students said that they got frustrated when they were working and had to stop writing to recharge their batteries. The freedom rendered by the lightweight notebook-style and portability of the Tandy are strong advantages counterbalancing the

> To sustain genuine innovation in a culture, educational or otherwise, means to perpetuate that innovation. The proof of concept of this educational culture will be a practice in which teachers and students are constantly learning from their experience, learning (to cite a small but telling case in point) that a technology with a more limited functionality can be most suitable if educational goals are well-defined.

complaints about the batteries.

While some writers might think the small LCD screen that can contain only eight lines of text might be a disadvantage, these young writers never expressed this was a drawback. In fact, Ms. Edinger suggested that it is just the right size for the length and quantity of paragraphs typically generated by students in this age group. In addition, the simplistic and limited technological capabilities of the Tandy laptop made its use by young writers easier to learn and more appropriate for their writing abilities than complex computers.

B. Benefits of the Technology

The students expressed many benefits of this technology. They liked that these computers were "kid-sized" and easy to carry around. Only one student said she would prefer to use a large full-scale computer for her writing.

In the area of revision, even these young writers felt revision was easier with the word processors. Michelle told me that "If you're writing a long story, and if you miss a paragraph, it's easier to put it in" with the Tandy. Dana also liked the fact that she could just "cut and paste" on the Tandy or make corrections in her spelling and mechanics.

All students I interviewed said the idea that the "spelling check" helped them. They could correct their spelling without an adult, and this independence fueled their writing confidence.

Neatness and the presentation of their published work also appealed to students. When you try to revise in handwriting, all the "stars" (asterisks) and writing "look too messed up," Michelle told me. Rebecca said that "it's easier to read when I write fast" on the computer than with her own handwriting. The fact that the text on the Tandy screen looks better seems to make the students feel better about their emerging texts. Since they like their texts more, they are more inclined to want to revise and extend or develop them.

> Specifically, a writing folder of student artifacts should be initiated and maintained as students involved in various "projects" go on to higher grades at Dalton. This folder should contain documents which all teachers could use to research their students' writing progress, among other skills.

I asked the students about composing with the Tandy, rather than with a pen. Allejandro told me that he was so used to the word processor now that he doesn't like to compose with a pen. Like other students I interviewed, he thinks he can work faster with the Tandy and that he's more likely to edit and revise his work. It may be due to the physical ease of typing as compared to the manual dexterity needed for handwriting. Students expressed that even erasing is easier on the Tandy, and "you don't get sore fingers" when you write with it.

It's not only physically easier to write with a word processor, some students believed that they thought differently. Ben said he got bored when he wrote with a pencil and would think about "what I would be doing instead of writing." But when he learned to use the Tandy to compose, he felt he could concentrate much better. Most of the students I interviewed made statements about how they could concentrate better when writing with the Tandy. It's interesting, however, that one student I interviewed had the opposite impression—he claimed he daydreamed less with a pencil in his hand, and his mind wandered off when he used the Tandy. This opposition in viewpoints about the word processors is proof of Joram's (1992) conclusion that "the effects of word processors interact with individual student differences and that researchers and writing teachers need to consider these potential differences when prescribing word processors for composition" (p. 167).

Not only did the Tandys appear to affect students' writing processes, when I examined samples of writing that students did throughout the year, I noticed several characteristics which recommend this project. Students had written a classroom magazine about the Anasazi Indians which contained an article researched and written by each member of the class. Each article focused on one aspect of Anasazi culture, ranging from history to cooking and weaving. I was extremely impressed with the quantity, quality and readability of the writing of these young students. Articles in this magazine ranged in length from 200 to 600 words, which certainly attests to the advanced level of these young writers. Every article was multiparagraphed, indicating students' knowledge of paragraph structure and essay organization.

I was particularly impressed with the audience awareness exhibited in the writing of these young students. Audience awareness is a skill many college students struggle to achieve in their writing as research by Flower (1979, 1981) indicates. Flower (1981) suggests that beginning and unskilled writers compose "writer-based prose," which is text written for the self and without the awareness of the needs of a reader. It is cognitively more difficult to compose with a reader in mind. To be aware of one's reader means the writer understands that every reader does not have the same perspective and background information as the writer. I found indications of audience awareness in the writing of Ms. Edinger's students. Use of writing devices like interrogative leads which invite a reader to continue, transitional devices like "first, second, and third," which order ideas, and logical connections like "even though" and "however" which weave coherence into writing suggest that students in her class have written "reader-based" prose. Such writing indicates an uncharacteristically high level of cognitive thinking achieved by these fourth grade writers.

Recommendations

In the "New Lab Proposal for Enhancement of the Fourth Grade Writing Project," Ms. Edinger suggested that assessment of the project should be done by teachers who are "kid watchers," a term coined by Ken Goodman. I suggest that teachers involved in projects like these also be trained as teacher-researchers, or to use Lawrence Stenhouse's term, action researchers. This is particularly justifiable in the case of The Dalton School and the projects undertaken by The New Laboratory for Teaching and Learning. According to one memorandum about "The Dalton Technology Plan," students involved in the projects "will need to become skilled explorers, not docile learners: teachers will become, not masters, but native guides, like Virgil to Dante, interpreting, elucidating, cautioning, exhorting." The concept of education as inquiry is basic to the stance adopted by the teacher-researcher. Stenhouse writes: "To call for research-based teaching is, I suggest, to ask us as teachers to share with our pupils or students the process of our learning the wisdom which we do not possess so that they can get into critical perspective the learning which we trust is ours" (1983, p. 113). The perspective of the teacher-researcher is one of explorer and learner. The teacher investigates the learning with his/her students. In order to evaluate learning *processes*, like the ones in place in the writing-process classroom, a stance of classroom researcher and system of inquiry might be helpful.

Specifically, a writing folder of student artifacts should be initiated and maintained as students involved in various "projects" go on to higher grades at Dalton. This folder should contain documents which all teachers could use to research their students' writing progress, among other skills. These folders might also supply data that could be used to compare the progress of students involved in the word-processing project to those who were not. In addition, Ms. Edinger's current practice of keeping writing samples from the school year enables her to study longitudinal progress, as well as compare writing done on the Tandys and in handwriting. These folders also contain self-evaluations of each writing project and provide useful information about student progress. Specific questions about the use of word processors would encourage metacognitive thinking as well as provide data about the project.

Instruments or surveys might be designed to assess students' progress in the writing process when using the Tandy. For example, when students write each day, they might tally a simple line count, and indicate the kind of revisions they made on a check list. Teachers might also want to get students to keep track of the time spent using the Tandy in relation to the number of lines of text generated. These simple studies would help the teacher monitor the level of revisions being done, as well as measure the fluency rate of students over the course of time. In addition, affective questions about students' feelings about the word processor as well as about writing might be helpful in assessing whether or not there is any relationship between motivation about writing and the use of the technology.

It is interesting that research on the use of word processors in writing suggests that writers using them revise more frequently than those who don't, but "these changes may primarily consist of surface level revision and other revising activities that are typical of immature writers" (Joram, 1992, p. 169). I observed a great deal of concern about spelling and all the students I interviewed commented about the spell-check device. I wondered if they were overly concerned with "surface level revision." It might be that the benefits of confidence and independence to these young writers might fuel them to move beyond the "surface-level errors" that more sophisticated writers reduce themselves to when they use word processors. The level, nature and frequency of their revisions could be studied by a teacher-researcher with the use of simple surveys or interviews about each day's revision activities or even random occasional counts and surveys. In addition, close observation and field notes of classroom activities and journals reflecting on classroom activity and student artifacts are ways for teacher researchers to explore and monitor the learning being done by their students.

Joram summarizes, "while the claim that word processors improve the quality of composition because they facilitate revision is intuitively appealing, there is little research that directly tests this claim" (1992, p. 168). Active and ongoing classroom research is a way to address the claims being made in the research community as well as a way for teachers and their students to investigate and document the learning processes that they explore as part of The New Lab's Projects. Teachers can obtain training as action researchers by taking graduate courses in education or by reading recent scholarship in the field. An alternative approach might be to enlist a consultant to mentor teachers involved in projects like this one as they develop a research design, collect and analyze data, report research findings, and develop new research strategies as the process evolves.

It seems appropriate that The Dalton School, whose original plan envisioned inquiry-based learning, be staffed by teachers who, as teacher-researchers, see themselves as collaborators in the inquiry process of their students, as they seek to describe, investigate, document, evaluate, and report this learning. The excellent learning environment fostered in Ms. Edinger's classroom is a propitious site for further research.

References

Daiute, C.A. (1983). The computer as stylus and audience. *College Composition and Communication, 34* (2), 135-147.

Flower, L. (1981). "Revising writer-based prose," *Journal of Basic Writing 3* (3), 62-74.

Joram, E., *et al.* (1992). "The effects of revising with a word processor on written composition." *Research in the teaching of English 26;2*, pp. 167-193.

McKenzie, J. (1984). Accordion writing—Expository composition with the word processor. *English Journal 73* (5), 56-58.

Stenhouse, L. (1983). "Research as a basis for teaching." In Rudduck, J. and Hopkins, D. (Eds.), *Research as a basis for teaching* (1985). London: Heinemann Educational Books.

Zinsser, W. (1983). *Writing with a word processor.* New York, NY: Harper and Row.

* * *

Evaluation of *Ecotype*: Michael R. Rampino, Associate Professor and Chair, Department of Applied Science, New York University

Introduction

What are the possibilities of having 6th graders do real scientific research? Before my visit to Dalton, I would have said rather poor. Although I have seen problem-oriented learning situations work well for high school and college students, and hands-on science is certainly widely used in elementary school settings, I thought that 6th graders were so young, and lacked so much of the scientific basics, that their ability to do really independent research, and to *discover* science for themselves, was practically nil. My observations of the *Ecotype* program at Dalton have changed my mind.

The *Ecotype* program was designed to help the students acquire a basic understanding of some of the fundamental concepts of geology (paleontology, stratigraphy, etc.), but more than that, it was designed specifically "to help students become confident learners, capable of independently addressing scientific questions." Its basic premise, therefore, is to move away from traditional teacher-centered learning, towards a format that more closely resembles real scientific research—and the tool that helps establish that format is the computer.

> A comparison of Professor Black's rigorous study of *Galileo* and *Archaeotype* with Professor Rampino's entirely independent, more qualitative evaluation of *Ecotype* would reveal a cluster of diagnostic signs—an educational syndrome, as it were. Sixth graders in *Ecotype* are not studying the computer; they are using the computer to study paleontology, and studying paleontology in a way that leads to an internalization of basic expository and research skills applicable to any domain.

The idea behind *Ecotype* is to have the students develop a working knowledge of the scientific method through the use of a computer simulation called "Dinosaur Canyon", in which they use their own skills of observation, description, deduction, and classification, and actually construct their own hypotheses and test them. Through *Ecotype* the students discover how to identify what questions are important and the best methods for answering those questions; how to make careful and objective observations, and keep an organized record of the evidence; how to make use of graphs and mathematics to analyze information; how to synthesize information, and work productively in groups; and how to write up their observations and results. In other words, the students work to acquire just the kinds of skills that *real* scientists must have. I was impressed by the *Ecotype* students' abilities in these real-world scientific activities.

The Visit to Dalton

I visited Dalton on three separate days (May 10, 12 and 13, 1993), and attended several *Ecotype* classes. I spent considerable time with the instructor and developer of *Ecotype*, Malcolm Fenton, discussing the program, and I talked with the students individually and in small groups during class time. Dr. Fenton demonstrated the details of the computer simulation called "Dinosaur Canyon" that the students use in *Ecotype* to explore the world of geology, and I must say that I became comfortable using the program instantly. It is quite transparent, and I could see its usefulness in the classroom—I wanted a copy immediately. The students I spoke with all agreed that they had no problems with handling the computer program, and they said that they enjoyed using it.

In the classes I observed, the students arrived in class and got right to work without any coaxing from the instructor. Almost everyone in the class had some project at the computer, or in using reference materials, that they were continuing from the last class meeting, and the class seemed to have its own momentum, a sign that the students were seriously engaged by what they were doing. Almost immediately there were questions for the instructor, and for me as well, since I was identified as a geologist. Because of their experience with Dr. Fenton, the students found it natural to treat anyone knowledgeable in the classroom as a resource.

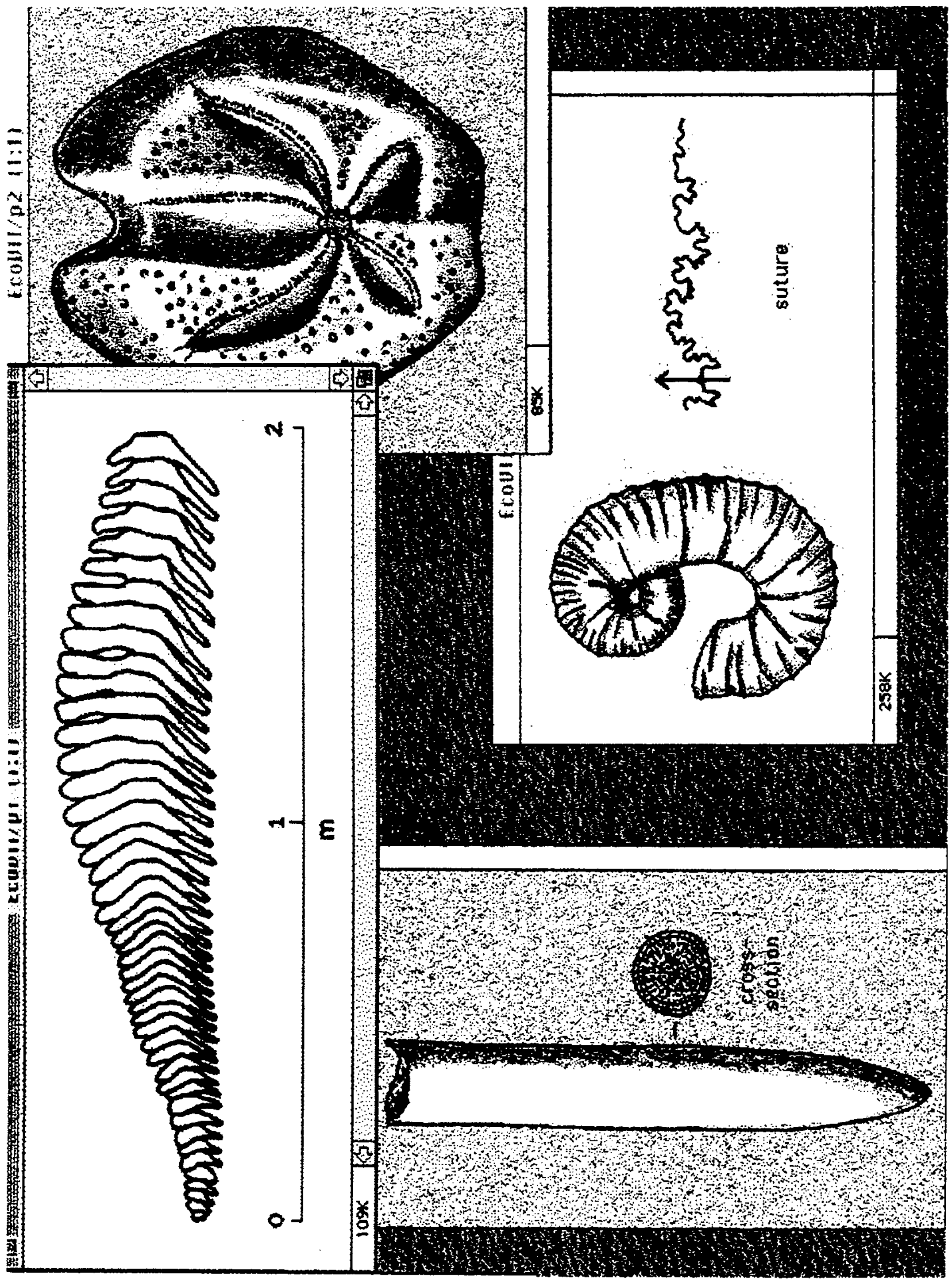
I discussed at length with Dr. Fenton the philosophy behind the development of the course, his experience actually running the course for the first time this year, and various problems that he foresaw, or which have developed during the course. Dr. Fenton supplied me with some very useful materials relating to *Ecotype*, including a brief history of the development of the course, and a journal or "*Ecotype* Diary" of the progress of the first trials of *Ecotype*, updated to the week of April 26.

During the class periods, I wandered around through the class, looking over students' shoulders, asking them questions about what they were doing, and about their opinions on the course in general, the instructor, and the *Ecotype* computer program. I asked students about their prior experience with earth science (most have had some that they learned in 4th and 5th grades but remembered little) and their understanding and retention of the *Ecotype* material, and tried to gauge their retention of the basics.

I asked the students to demonstrate their use of the *Ecotype* computer program, and I also examined the written reports of their observations and discoveries. What follows are my observations on what I believe are the most important aspects of the course.

Use of Classroom Time and Space

The *Ecotype* classes meet for three 50-minute periods per week. Two classes are involved in the first trial of the *Ecotype* program, one with 17 students, the other with 10 students. The students within the *Ecotype* classes work in small groups of 3 students each on individual computers. These student groups were created by the students themselves, and as there was a tendency for boys and girls to form separate groups, Dr. Fenton made some effort to make the groups more heterogeneous with respect to gender. In the classes I observed, the students arrived in class and got right to work without any coaxing from the instructor. Almost everyone in the class had some project at the computer, or in using reference materials, that they were continuing from the last class meeting, and the class seemed to have its own momentum, a sign that the students were seriously engaged by what they were doing. Almost immediately there were questions for the instructor, and for me as well, since I was identified



Fossils found in the *Ecotype* simulation a geologist. Because of their experience with Dr. Fenton, the students found it natural to treat anyone knowledgeable in the classroom as a resource.

Ecotype workspace is well-lit and spacious, and the computer facilities seem to be excellent for the relatively small number of students in the classes. There is plenty of room for the students to work with the computers, on their lab reports, and with the extensive reference materials (textbooks, fossil encyclopedias, etc.) available in the laboratory. The lab seems to have been set up for other purposes, however, and in the future it might be helpful to have a workspace dedicated specifically to *Ecotype*, or to courses like it (*Project Galileo*, etc.), especially if these are expanded.

> Both Dr. Fenton and I wanted the student to get the right answer, and I was tempted to try to lead her in that direction. But after talking things over with Dr. Fenton, I realized that what was going on was even more important—she was engaged in the scientific process. She was doing just what *Ecotype* was about—scientific research—with all of its possible frustrations and blind alleys.

Interaction Among the Students and With the Instructor

Ecotype involves considerable group effort and sharing of tasks. The students interact with each other in the small groups and with the instructor almost continually during the class time. Information sharing seems to be very important (especially with the Dinosaur Canyon program in which students are involved in dating geologic formations) and students from one group will often visit other groups to see what they are doing, and how the other group's findings relate to their own work. Students are continuously, but variously, engaged in various aspects of the *Ecotype* work—using the computer program, trying to identify rocks and fossils using the reference material, drawing pictures of fossil reconstructions, and/or writing up reports of their observations. Only a few students seemed willing to "coast" and let the others in their group do most of the work.

According to the diary and conversations with students and Dr. Fenton, some students were somewhat less engaged in early classes that were teacher-centered (e.g., lectures on fossil identification and reconstructions). However, in the "hands-on" lessons that I observed, most of the students were working hard, and were not easily distracted from the tasks at hand. Most of this activity was student-generated—the motivation for doing specific tasks came directly from the students, and not from the instructor. Interesting ideas emerged directly from the students' work, and Dr. Fenton clearly encourages the students to follow up on their ideas—he definitely does not try to lead them in directions of his own.

For example, one girl was studying the partial fossil of an extinct whale, but she had identified it as a marine reptile—an ichthyosaur. She was so excited by her discovery, and so interested in ichthyosaurs in general, that she did extra research on these swimming reptiles. The skeletons of whales and ichthyosaurs are somewhat similar, and in fact, the skeletons of extinct whales were confused with ichthyosaurs by some early paleontologists. Both Dr. Fenton and I wanted the student to get the right answer, and I was tempted to try to lead her in that direction. But after talking things over with Dr. Fenton, I realized that what was going on was even more important—she was engaged in the scientific process. She was doing just what *Ecotype* was about—scientific research—with all of its possible frustrations and blind alleys.

At some point, I hoped, she would realize her mistake, and the light bulb would come on. She could then experience what all scientists hope for—the thrill of the Eureka phenomenon, the real thing! (In fact, in the last class that I observed, she realized her mistake, and went on with her studies of whales. She wasn't at all shattered by the experience, and I saw that she had learned something that allowed her to do better work. She was now more careful in her identifications—she wouldn't be fooled again.)

Teacher Commitment

Dr. Fenton has been a key factor in all of the conceptualization and development of the *Ecotype* program. For example, he is responsible for the Dinosaur Canyon concept and design, and he has carefully documented all aspects of the course, which will be especially valuable as other instructors come into the *Ecotype* program.

In the situation with *Ecotype*, the instructor is really more of a research advisor or mentor, and Dr. Fenton is very effective in that role. He is committed to student-centered learning, and he has the quite remarkable ability to allow the students to do their own discovering no matter what directions they take. As he told me, "The function of the teacher is to help the students ask useful questions." I was impressed by the way in which he helped the students ask those questions without substituting questions of his own, as so often happens in classes of this sort.

Several times during my class visits, I was tempted to correct a student's mistaken identification, or guide them directly to the correct picture of a fossil in a book to help them identify it, but Dr. Fenton is very careful to remain true to the philosophy behind the *Ecotype* course. He will help students, but often by answering a question with another question to gently nudge the student, and he will do everything he can not to interfere with their own discovery process. The instructor asked questions such as, "What do *you* think is important?" or, "Why do *you* say that?", drawing out ideas and hypotheses about what was going on geologically.

Dr. Fenton is constantly thinking of new ways to enrich the students' experience. Early in the semester, when he thought that they needed additional hands-on experience at identifying rocks, he took them to examine the building stones in the neighborhood. The students that I spoke with said that they had enjoyed the trip, and that it helped them considerably with rock identification. Dr. Fenton also prepared helpful identification guides for the course.

Dr. Fenton is attentive to students, following the development of their scientific discovery in each of his students—and in every case in which I asked about a particular child, he could tell me what they were doing, and how they were progressing in their thinking.

Getting young children to follow through on their own ideas is a great challenge, and one that is easily missed if an instructor becomes impatient with students who are literally "reinventing the wheel" of scientific research. Dr. Fenton's patience, commitment, and seemingly tireless efforts in developing and following through on the classroom testing of *Ecotype* are quite impressive.

Program Structure and Subject Matter

Ecotype consists of a computer simulation of a geological section through a canyon (Dinosaur Canyon). Each student group is assigned a portion of the section to study. Major geological features may be observed at each location, and the students find fossils and take rock samples, recording their provenance on a print-out of their study location. The rocks and fossils are then "removed" to a simulated lab for analysis. Rocks can be identified, examined under a microscope, chemically analyzed, and dated, and fossils can be examined, measured, and printed out on a separate sheet. This is all done on the computer. Once the evidence is obtained, the students commence their independent and group research.

The *Ecotype* Project was inspired by *Archaeotype*, the program at Dalton in which students use a computer environment to simulate an archeological "dig" where they recover and identify artifacts, and reconstruct ancient cultures using the same techniques as real archeologists.

In *Ecotype*, each group first investigates a horizontal surface in the canyon (where the sediments are the same age), and works to reconstruct the paleoenvironment. The students also work on a cliff surface within the canyon, and try to reconstruct the geological history from the rock sequences.

Throughout this process, the students work very much in the manner of research geologists. They do field studies using maps, they take samples and analyze them, and they conduct research by studying reference material, by experimentation, and through discussions with colleagues. They are required to write interim and final reports on their work, and to present these to their peers.

In the first two weeks of *Ecotype* class meetings, students were introduced to the Dinosaur Canyon program, and they watched videos from the PBS series "Dinosaur" showing earth scientists in the field searching for fossils, and bringing them back to the lab for interpretation. The paleontologists reconstructed the skeletons, and discussed the biology of the creatures, and the environments in which they lived.

Part of the early class periods was devoted to discussions of fossils, and examination of hand specimens of fossils and rocks. The students were asked to sketch, measure, describe, and identify the fossils, and state how he/she thought the animal moved, ate, what it looked like in life, where it lived, etc. Students identified rocks with a rock identification guide prepared by Dr. Fenton. They were asked to describe the rock's texture, grain size, structure, color and response to scratch and acid tests. Several times, I observed Dr. Fenton helping students test rocks with acid, and discussing the details of rock identification with student groups.

From the beginning, quality and not quantity of work was stressed, and this was something I saw many times in the classes I observed—the students were concerned about doing a good job at identification and recording. Of course, there were some students who just plunged ahead, but some professional geologists are the same way.

Much use was made of a fossil guide that Dr. Fenton prepared for the course, and also of published material on identifying fossils. Students said that they liked to identify the fossils, and they liked the hands-on nature of the course right away. Some students had some problems imagining what the fossil organisms looked like when alive, and, therefore, some additional time was spent on reconstructions of fossils of various organisms.

> When Dr. Fenton threw the students a curve ball—rocks composed of particles that formed a long time before the rocks themselves—they figured it out. For example, "One drawback in our theory was in several limestones which we found. The minimum age of each was one hundred fifty million years before the beginning of the Cretaceous. Our hypothesis is that the individual particles of the sedimentary limestones were formed one hundred fifty million years before the Cretaceous."

The students at first concentrated on developing their skills of observation, description, deduction, and classification, but they soon began to construct hypotheses to explain their observations. Their use of hypothesis, experiment, and of reference material expanded further as the program continued, and when I made my observations the class was fully involved in this work.

Students have access to an extraordinary amount of reference material—books on rocks, fossils, dinosaurs, paleoenvironments, reconstructions, etc. The classroom is a rich learning experience. They are also permitted to visit the Dalton library to access research material that may not be covered in the references available in class.

The students get their notebooks at the beginning of the class, and then they start research or work on the computer. A large amount of data is acquired from the geologic sites, and the students learn how to collate and organize the information. Students fill out record sheets for each location, and they were asked to make a computer print-out for each excavation they studied. They sampled and identified the rocks and fossils. In this way, they are taught to behave like professional geologists in the field and laboratory, documenting all aspects of their research findings.

The students were required to write reports that consisted of a summary of the most important features and facts discovered by each group at their first location. According to Dr. Fenton, the objective was to focus the students' research and to help them to ask important questions about their locations. Working on these reports led to further possible research directions, and most students saw this as a challenge. For example, I spent some time working with one boy who came upon the idea of calculating the rate of deposition of sediments from knowing the thickness and age of the sediments in the canyon. However, some students tried to get the teacher to define the important geological questions, rather than exploring the possibilities for themselves.

Classroom Atmosphere, Attitudes and Student Achievement

Dr. Fenton realized quite early on that the net result of the Dinosaur Canyon project was as if he had transported the students to a different planet, and asked them to study it. Everything about the subject was new to the students. As I observed, they had very little recall of terms and concepts that were taught in their previous exposure to earth science (names of rock types, etc.). They were really starting from scratch, and it was fascinating to see how the development of the students' ideas paralleled the history of development of ideas in the geological sciences. For example, only towards the end of the third week did they think to ask what geological era the fossils came from. I note that it wasn't until the 19th century that geologists started to arrange geological time into periods.

Ecotype involves truly student-centered learning, very similar to what I had seen in the *Project Galileo* Astronomy class for higher level students. Kids are mostly answer-oriented, and Dr. Fenton realized quite early that he was providing a new environment for the kids in which "their" questions were important. In addition to the tasks of identifying fossils and environments, the work done by the students generated hypotheses about all sorts of "related" problems in paleontology and geology, which the students were free to explore. For example, in one group, after identifying a dinosaur trackway, several students took up, on their own, the idea of how dinosaur size could be determined from the spacing between dinosaur footprints.

The student reports made interesting reading. Most of the reports were well-written, and dealt with important issues such as the date, environment, and range of fossils, in perceptive and imaginative ways. For example, one group determined from their reconstructions that "... the Ichthyosaur we found swam only and couldn't walk very easily if not at all, because of the way its bones are constructed." The type of fossils collected led to the conclusion that, "I believe that the location that my group and I are digging in was once underwater...We found various mollusks (mostly gastropods) coils, fish, two ichthyosaurs and many sea urchins. At first it was hard to believe that snails could live underwater, but the earth is an amazing place."

The students were rightfully cautious in dating their excavations—"The reason our area is late, and not early Mesozoic era, is because we have found only one dinosaur." or "I am not sure yet what the date of our site is. From the time periods we have of the fish and the ichthyosaur, it probably dated from between 213 to 65 million years ago. I must do more research on the time period of our site and more work must be done for the site." They were also cautious in their hypothesizing about larger questions: "I think that I should see what there is in the other squares before I make a hypothesis on the extinction of the dinosaurs."

The students have learned how to hypothesize based on the evidence—"I think this (that the site was once under water) because of three specific fossils that Julie and I found. One was half the skeleton of an Ichthyosaur. The other two were echinoderms, fossil sea urchins." "Our hypothesis is that location 80 is an area covered with shallow seawater with a hard limestone floor under it. The sea was from the Cretaceous Period, a time when the earth had a warm climate, that took place between 135 and 65 million years ago."

When Dr. Fenton threw the students a curve ball—rocks composed of particles that formed a long time before the rocks themselves—they figured it out. For example, "One drawback in our theory was in several limestones which we found. The minimum age of each was one hundred fifty million years before the beginning of the Cretaceous. Our hypothesis is that the individual particles of the sedimentary limestones were formed one hundred fifty million years before the Cretaceous." This shows that they were learning important geological concepts while working to identify their fossils and rocks.

I was happy to see that the students had no problems changing their minds after making a wrong identification ("In my first report I stated that these were 'parachute seeds', I was wrong. They are really sea plants."). When another group of students found a Pterosaur in sediments that they had identified as marine, they were able to hypothesize how the flying reptile could have ended up in the marine environment.

Spin-off projects also occurred, as in real scientific research—"Another research plan I am following is finding out the speed of the smaller bird-like animal. Eli, Robert and I have figured the pace to be 0.56 seconds per 2 meters, this we have figured out after many mathematical difficulties (We plan to convert this to kilometers per hour in later reports)." "A part of research which I am doing alone is the research on a 'nest' (our name for it)... I am going to do more research on this particular part, since it is really *my* theory."

In some groups, one student in the group became the "expert" on a particular aspect of the research; it was interesting to see such "specialization" at such a basic stage of research. For example, in one group, a student had great pride in the fact that he was the insect expert, and whenever a fossil insect was found, he had the job of identifying it. Perhaps there is something natural about wanting to be seen as an expert in one particular area or another.

> Many things that I learned, e.g., the geologic timescale, were not really retained until I used them as part of my everyday research. The *Ecotype* students' knowledge is the kind one gets from a working familiarity with the subject matter.

Use of Computers

The practicalities involved in conventional geological studies (field trips, etc.) can make it difficult for younger students to become actively involved in research-based learning. The use of computers can overcome this problem by bringing geology into the classroom in the form of a computer simulation. *Ecotype* is a simulated environment in which the students gather "objects" and investigate them in a "lab" setting. The students were apparently enthusiastic about using computers from the first, and they were apparently comfortable at using the program. None of the students observed during my time in class had difficulty with manipulating the *Ecotype* program.

My observations confirm that the *Ecotype* computer program is almost completely invisible to the students. They behave in it pretty much the way a geologist would behave in the field, sampling rocks and fossils, and bringing samples back to the laboratory for identification and dating. I saw no examples of manipulation of the program getting in the way of a student understanding of what he or she was doing at any time.

The program was put together by Dr. Fenton (original concept, scientific design and image production) and Dr. Rachel Bellamy (programming and interface design), who was a Dalton employee (in The New Lab) and now works for Apple. The program seems to be a robust and reliable prototype, with only some minor bugs. The bugs do not seem to be serious, and have not caused data to be corrupted. Segments of the prototype crashed on only two occasions, when there was a loss of all unrecorded data. One recurring computer problem is the slow print-out of figures from the geologic localities, but this can be remedied in the future.

Possibilities

Ecotype is just beginning; this year represents the introductory experimental phase. Naturally, the possibilities for expanding this course in the future are great. All sixth-grade students at Dalton could eventually take *Ecotype* as part of their science curriculum. Of course, such expansion of *Ecotype* would require instructors trained to use the computer in a problem-solving environment, and here Dr. Fenton's help would be a boon.

There are also great possibilities in the dissemination of *Ecotype* courses outside of Dalton. It will be a great challenge to attempt to transfer *Ecotype* to schools with resources that are more constrained, and student populations that are less advantaged. This would be no small task, but I see it as a necessary step if this type of science course is to be seen as a real alternative to traditional science teaching.

Recommendations

It is difficult to make recommendations that have not already been considered by Dr. Fenton in his intense personal evaluation of the course and its objectives. The course was obviously carefully planned, and from what I have seen it runs quite well.

However, several possible improvements were discussed. Dinosaur Canyon now begins with the simulation but it might help if students had more background first. Class periods might be expanded, as I saw students struggling to complete a specific task as the period came to a close. More videos might be helpful in the introductory portion of the course to improve the student visualization of some of the concepts involved in stratigraphy and paleontological reconstructions. Many of the small bugs in the course will no doubt be fixed by the end of the first year.

Summary

The *Ecotype* program was developed to give students an understanding of the fundamentals, but at the same time to allow the students to discover important questions in geological studies, and to answer those questions for themselves. In *Ecotype*, these goals are arrived at through a very successful computer simulation.

The students have apparently learned quite a lot of geology in *Ecotype*, and they have learned it "from the ground up." The breadth of their interest can be seen in their final reports, in which individual students wrote on such varied topics as the origin of limestones, pterosaurs, Darwinian evolution, the habitat and diet of heart urchins, and calculating the length of a dinosaur from the size of its footprints. Their retention of the new subject matter is good because they have used the material in a real research setting. This is similar to my own experience as a student and later as a researcher. Many things that I learned, e.g. the geologic timescale, were not really retained until I used them as part of my everyday research. The *Ecotype* students' knowledge is the kind one gets from a working familiarity with the subject matter.

From my observations, I can say that *Ecotype* is providing students with an effective introduction to the workings of science. The computer program is an excellent way for the students to gather and investigate geologic data in class, and it leads them naturally to utilize other sources of information. The open-ended structure of the class allows them to ask questions, formulate thypotheses, and test them in the information environment consisting of the computer program, the instructor, and a wealth of outside references. These 6th grade students are gaining a real working knowledge of the scientific method by actually doing science. I am impressed. My overall rating of the course in terms of concept, implementation, and results thus far in the first year is excellent.

***

Evaluation of the *Archaeotype* Project: Mark Petrini, Associate Professor of Classics, Columbia University

To complete this evaluation I spent three days at Dalton, mornings and afternoons, from May 19-21, 1993. I observed four different classes, and interviewed teachers and program developers: Mary Kate Brown, Neil Goldberg, Carolyn Karp, and Bill Waldman. I spent a number of hours reviewing the support collection in the library. I also met with students, both individually and in groups, to get a direct sense of what they had learned, and how they felt about their work. In all, I spent about fourteen hours at Dalton. As a final step, I have studied two videos of *Archaeotype* in action, one a professional production, the other an in-house version by members of the team.

Background

> As the chair of the departmental computer committee at Columbia for the past seven years, I have regularly received new educational software; I have almost never seen anything I would bother to use myself, or in which I would invest departmental resources....Given this disappointing history, my first thought in looking at *Archaeotype* was "this is it."...Other programs (like traditional teaching modes) are concerned with the transmission of information; *Archaeotype* teaches students how to learn, how to synthesize what they have learned—in short, how to think.

My first reactions to the *Archaeotype* Program in the spring of 1992 were surprise and enthusiasm. As a latecomer to the computer revolution (one of the generation of students who did not acquire their first computers until college or graduate school), I have often heard the opinion that in due time American education would be transformed by this new technology, and that Classical Studies, moribund though the field is, would undergo a revolution. To date, I know of no colleague who has seen any changes approaching those early expectations. Word-searches, editing, data storage and retrieval have, of course, gotten easier, but the heart of the computer contribution to scholarship and pedagogy in the humanities has been to provide people with better typewriters. As the chair of the departmental computer committee at Columbia for the past seven years, I have regularly received new educational software; I have almost never seen anything I would bother to use myself, or in which I would invest departmental resources.

The obstacles to a productive union of Classical Studies and Computer Science are formidable. The two disciplines don't speak the same language; there is no apparent overlap of shared skills, no obvious place to begin a fruitful interaction. Most significantly, there is only a tiny handful of people with expertise in both areas.

Given this disappointing history, my first thought in looking at *Archaeotype* was "this is it." *Archaeotype* is a unique amalgam of imaginative technology and of classical scholarship. The program, furthermore, represents what no other teaching software in my experience has even hinted at: a clear and sophisticated vision of how to teach classical antiquity, and a firm understanding of the important lessons to be learned from studying the past. Other programs (like traditional teaching modes) are concerned with the transmission of information; *Archaeotype* teaches students how to learn, how to synthesize what they have learned—in short, how to think.

Students at work on *Archaeotype*

Archaeotype One Year Later

My time spent observing classes this year seemed much the same as last. Students walk into the classroom and begin working on their own. They have formed coherent teams with individual areas of expertise and interest. Students never work (and the program will not allow them to work) on objects in isolation: one discovery always leads to another, the slow uncovering of a site is in fact the construction of a web of knowledge, in which questions about the most recent finds are answered by earlier objects. Members of the group who are particularly good at identifying armor, or who know geography, or have worked before with ostraka, are freely consulted by other students. There is an unmistakable attitude of independence and self-motivation, of student ownership in the project, which increases palpably as the work progresses. The teacher in the classroom acts as a kind of expert consultant for the student teams, not as the source of absolute truth and final answers. The sight of a room full of sixth-graders poring over temple fragments and bits of armor, and debating the implications of provenance with a trained archeologist, is something anyone interested in education should see at least once.

These were precisely the qualities that so impressed me last year, and I was pleased to see that they were not accidents of personnel or beginner's luck—the enthusiasm and energy which often make a first project a success, but an unrepeatable one. It was especially instructive to see a class and a teacher (Carolyn Karp) whom I had not observed last year: I found the same atmosphere and program results as I had seen in other instructors with other students. The best features of the program are permanent and reproducible, year after year, from one class to the next.

On the technical end of things, the program seemed to run more smoothly than it had in the past. Last year's version had a few technical bugs, mainly consisting of bottlenecks which slowed down the operation: the "Museum," for example, could only be accessed by one student at a time. These seem now to have been worked out, and there was a sense of greater ease and familiarity on the part of faculty and students. There is also a new HyperCard notebook program in which students informally record their observations: these are not finished descriptions, but works in progress to which each member of the group contributes and which groups can share with other groups. It represents a slightly more permanent version of students orally exchanging information across a room, a kind of ongoing, written debate about artifacts and hypotheses. I was impressed with this new feature, and I hope that its use is encouraged even more in the future.

Detailed Observations of Archaeotype *in Action*

I would like to describe the work done by students in the *Archaeotype* sessions that I observed this year; I add this description precisely because it repeats the details of last year's evaluation; i.e., because it confirms how effectively and with what ease the program guides students through its paces. Teams of three or four students begin by uncovering small areas of the archeological field. As objects emerge from the soil, they are weighed, measured, and taken to the museum. In a typical case, a student team uncovered a coin; one student began to look through the Perseus disk and through books in the reference collection to find similar coin-types; another transcribed the inscription and asked for help in deciphering it; the third student, once it was determined that the coin was Syracusan, began to go through maps to find Syracuse. Tentative speculation was begun on how a Sicilian coin might have ended up in the site; these were included in the group notes.

There is real excitement and a sense of fun at this stage of the project: the work is done with constant discussion within the group and with other groups. It is typical that only when the students themselves reach an impasse (when their resources are finally exhausted) does the teacher receive an appeal for help; help arrives in the form of clarification or additional information, not final arbitration.

The next (the "physical") stage of the work in the original *Archaeotype* consists of attaching an image of the object to a map of the field, representing its location in the site and its relationship to other objects found there. The Assyrian Project has a wonderful improvement at this point in the operation, in which students build a three-dimensional model of the site. Walls, towers, and buildings are constructed roughly to scale out of cardboard and attached to the site-map; as pieces are added, the site grows and takes shape. When it is finished, students have a far clearer idea of how the actual site looks and how the objects found there relate to one another. The building of these models is an important step forward in the program, and should be done whenever possible.

A second example of student work succinctly conveys the strength of *Archaeotype* program. I watched a group of students uncover a fragment of stone which had no obvious defining features; it could have come (at least to my eyes) from several different structures, and I expected the students to make nothing of it. As the group discussed the object, one student remembered a similar object on a vase painting which they had seen a few weeks before. Most impressively, it was not an artifact that they had themselves actually uncovered (and would therefore remember more easily) but it had appeared on a vase which had been viewed on the Perseus video disk, of the death of Priam at the family altar. The student remembered the shape of the altar from the vase painting and deduced, probably correctly, that the object found in the field was from an altar. This kind of visual memory is impressive to find in any student, and remarkable in one so young.

I was further impressed by the students' subsequent discussion of the story of Aeneas and the fall of Troy. Those of us who teach classics are constantly asked questions about the "myth of Aeneas" or the "myth of Medea." The assumption behind these questions, of course, is that there *is* a myth of Aeneas, that "myth" comprises a canonical body of narratives which "the Greeks" collected, edited, and finally authorized with some sort of imprimatur. It takes considerable effort to convince students that Greece and Rome had no "bible," and that "myth" is a fluid, evolving collection of *versions* of stories which are freely manipulated to serve different literary, political, or religious ends. The students in the *Archaeotype* group not only knew a story of the fall of Troy (an impressive fact on its own) but also knew that there were different sources and varying accounts of the legend. I asked them more questions and had a second discussion about the death of Ajax and the character of Odysseus. *Archaeotype* presents students with a wide spectrum of visual images, giving them firsthand experience of the ways in which versions Greek myth can at times conform, and at other times can conflict, with more familiar written accounts.

Additional Observations

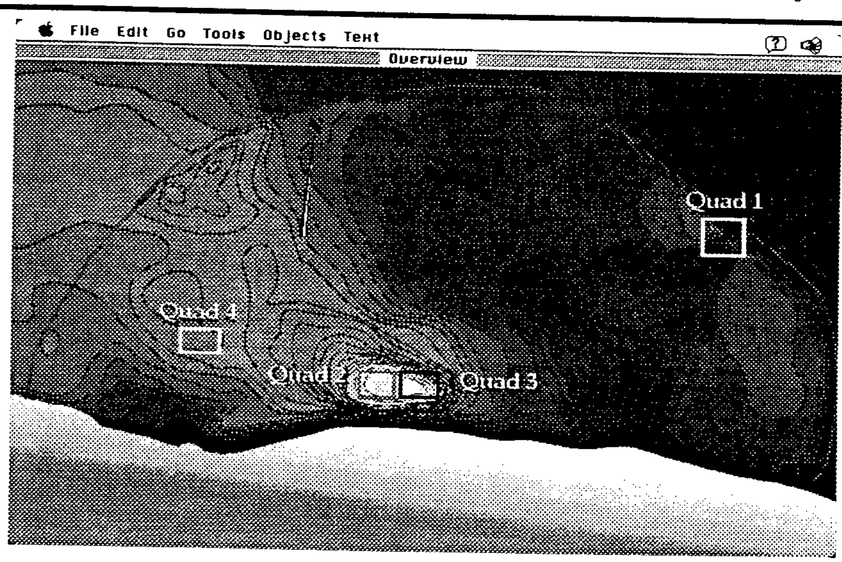
My final comments on the Greek portion of the program concern supplementary classroom work. For my first look at *Archaeotype* in 1992, I concentrated primarily on watching how the students interacted with the technology. I made it a point in this viewing, therefore, to observe a more traditional class session, and to see how the computer learning fits together with the other parts of the curriculum.

The class I attended looked a great deal like any other class. Students read and took notes from a text which gave a survey of Greek culture and history; this session was followed by a quiz, and then a discussion period. The subject was the Greek *polis*, and students spoke with impressive awareness of the relationship between geography and Greek political life. They knew the important differences between Athens and Sparta, and the role that each had played in the wars of the fifth century BCE.

What seemed different from a traditional classroom setting was the ease with which students moved through the material. For most other students in my experience, the history of Greek culture is a two-dimensional list of names, dates, and events, occasionally fleshed out with a slide or two; facts are presented and absorbed, and rarely "come to life" until much later in a student's career—perhaps until they visit a Greek theater and imagine the performance of a tragedy, or visit the site of a battle, or the ruins of a temple. Sixth-graders at Dalton, on the other hand, have never had antiquity presented to them as a catalogue of facts. The classical world has been experienced through pictures as well as through words, through the realities of architecture, city-streets, and daily apparel, as well as through literary and documentary texts. Students seem to *own* this material in a way that only comes from "holding" (in the sense that *Archaeotype* allows) the concrete objects of another culture in their hands.

The Assyrian Project

Both this year's *Archaeotype* Program and the original were simulations: the artifacts were real, and their occurrence together in the same place historically plausible, but not actual. This approach has benefits, both practical and pedagogical. Pictures of artifacts for the program are scanned from publications which are already in the school library or which can be easily obtained; artifacts are chosen which are sufficiently well-known or so well-represented that objects for comparison can be found in books or in museum collections. More important, in creating a site the designers of the program can cover more material and present a greater sweep of history than any real site could provide: Iron Age helmets, Periclean column bases, and fragments of the *Res Gestae* in a single location allow teachers to treat almost thousand years of human events through a discussion of major archeological



Assyrian Site

discoveries.

The newest version of *Archaeotype*, the Assyrian Project, is a departure from this practice, and it represents a remarkable step forward in the evolution of the program as a whole. The ambitiousness of this undertaking deserves special mention. The culture of classical western antiquity is in the public domain, so to speak, and has been fixed (for better or for worse) in a familiar matrix of artistic and philosophical commonplaces: we model post-offices, libraries, and museums on Greek architecture; we claim to have inherited democracy from Athens; to Homer, to Vergil, and to the tragedians we credit our sense of the individual. These may be simplistic and unsatisfying clichés, but they at least provide a beginning, some foundation from which a more sophisticated understanding of the past can be developed.

The municipal architecture of American towns, on the other hand, is never *ersatz* Assyrian. To put it simply, the pieces uncovered in this new *Archaeotype* program look very strange; the inhabitants of the site use a language which is nothing like our own; their literary texts are not the models for modern novels or for family drama; their thoughts about their own lives and their world are still obscure. This program is a more dramatic test of the ability of *Archaeotype* to teach students the skills of observation, the subtle use of inference and analogy, and the limits of hypothesis.

The chosen site was Til Barsip, a trading post on the banks of the Euphrates in Asia Minor. The site itself is much larger than the area-simulations used for the Greek project; there is also a greater variety of artifacts, which seem generally more difficult to identify. Fragments of city walls remain, and building foundations suggest streets, armories, shops, and warehouses.

I was excited by every aspect of the new project—philosophical, technical, and pedagogical, and I will discuss each of these in turn. I would like to begin my discussion with the philosophical implications of the new *Archaeotype*; I consider them significant enough alone to justify the whole program's existence.

The Assyrian Project has appeared at a time when Classical Studies is undergoing a much-needed period of reflection and self-evaluation. Assertions of the uniqueness of Greek culture (we should almost say Athenian) and of the childlike barbarity of all other contemporary cultures have been pervasive in the popular imagination and in the scholarship of this century. I am by no means in agreement with the more sensational rebuttals (Martin Bernal's *Black Athena*, for example) but they do serve to remind us that modern claims for an insular and inviolate Greece contradict both the material evidence and what the Greeks themselves say about their own heritage, especially before the Persian Wars, before the fierce nationalism of the fifth century made such comments unfashionable. Few people, to cite a single example, who read *Gilgamesh* and the *Iliad* side by side could doubt that the two poetic traditions were in contact at some point.

From documentary evidence, we know beyond question that there were constant and fruitful exchanges between Europe and the Near East *at least* by the seventh and sixth centuries BCE—from the first moment, that is, that any documentary evidence for Greece begins. The problems in delineating these points of contact are, to say the least, complex, and are not likely to be resolved in the near future. But it is clearly time that we in the field begin to view Classical Studies differently—to consider the ancient world as a richer and more interesting mix of people and cultures than is currently our practice.

The contribution that the expanded *Archaeotype* program can make to this transformation of the field is considerable. Through the Assyrian Project students are introduced to a broader and more generously-defined antiquity than most students meet, to an antiquity which much more nearly resembles the realities of the ancient world. The Near East is no longer treated as an account of "the other," whose culture and traditions are only valuable as foils to those of Greece. The program treats artifacts of every culture equally: these objects have artistic and historical significance; they are the products of real people, and they give those people faces and identities that will never emerge from even the best-written textbook. The history of any culture as foreign as that of the Near East would seem to me nearly unteachable at a middle-school level without *Archaeotype*, or something much like it, which can provide a visual and "tactile" complement to the written word.

> A student speculated that the wall of the city had been 50 to 60 feet high; when the question came back, "Do we have any evidence for the height of the walls?" there was a chorus of "No's" from the other students in the group. These are ways of thinking and ways of learning that don't change if one student reads more slowly, or another resists memorization.

The choice of Assyria is an ambitious test for *Archaeotype*, but I have come to the conclusion that the difficulty of the Assyrian site has direct pedagogical benefit. The challenge of reconstructing a real site, with buildings, storehouses, guardposts, as well as of incorporating statuary, vases, and coins, forces students to use their imagination with more rigor and more focus than the Greek material requires. They need to understand not simply that a stone in their quadrant is a fragment of a wall, but how it fits with other fragments in other quadrants; they next must consider why the wall was put there, how high it might have been, and against whom it might have been built as protection. Furthermore, students are forced to confront the limits of information and of hypothesis in a new way. So much (relatively) is known about the Greek world that gaps in the story of a site can often be filled (though cautiously) from other sources. With the Assyrian Project, these gaps will more likely remain; the "familiar matrix" I described above for Athens does not exist for the Near East, and the archeological sites and their objects are usually less well understood. The skills of observation and inference, therefore, are more purely applied, and students must live with the fact that very little certainty is possible in looking at the ancient past.

In evaluating the Assyrian Project, I felt that the program had been taken to a new level. It has become less of a tool (albeit an impressive and effective tool) for conveying the history of antiquity, and more of a direct window to the ancient world. The use of an actual archeological site is an experiment which is an unqualified success, and which should be repeated as soon as possible.

Further Comments

The most impressive part of this evaluative process was watching the videotape of the Assyrian Project in action. One of the site quadrants was excavated by a team of students who were not as accustomed to academic success as some of their classmates. The video recorded their work and their reactions to it. It was easy to understand how valuable this process had been for them and to hear the sense of accomplishment in their voices as they presented their results. The students had been able to identify some of the buildings and parts of the city walls, and had succeeded in constructing a three-dimensional scale model of the site from cardboard. Their reactions to their work were especially striking: they said over and over again "we can work at our own pace." They identified themselves as students who had always had trouble with books and traditional classroom learning, and they were explicit about the advantages they found in working with *Archaeotype*.

> I would very strongly recommend that still more efforts be made to link the study of primary objects to the study of primary texts. The textbooks for students at the middle-school level (to judge by the books I have seen at Dalton and elsewhere) seem generally cursory and dull; until better ones are available, why not use primary sources?...The conjoining of archeological material (through *Archaeotype*, slides, museum visits, etc.) with literary and historical texts in a semester-long project on a specific period of Greek history would be productive enough and rich enough to justify the investment of time and resources.

These differences impressed me as real and valuable. There are strengths and abilities in many students which the traditional classroom will never identify or develop. Because *Archaeotype* demands so many different kinds of skills, it is a wonderfully effective probe for finding these hidden abilities; and I suspect that the program is especially effective for dealing with students who find more traditional classroom setting difficult. Each team excavates its own quadrant, and each group progresses at its own pace, but the lessons are the same. A student speculated that the wall of the city had been 50 to 60 feet high; when the question came back, "Do we have any evidence for the height of the walls?" there was a chorus of "No's" from the other students in the group. These are ways of thinking and ways of learning that don't change if one student reads more slowly, or another resists memorization.

Recommendations

It would be natural for the program to follow up the success of the Assyrian Project with an actual Greek historical site. One suggestion (of the dozens possible) might be a site in Sicily. In the fields outside of Syracuse there are battlegrounds where the Athenians suffered their final, decisive losses of the Peloponnesian War. The sites are small enough to be adapted to the *Archaeotype* format, but are important enough to yield up objects of real significance: fortifications remain with their battlements and living quarters relatively intact, and there are abundant artifacts. Most important, from the sites and their artifacts a coherent narrative can be readily constructed of perhaps the most remarkable period in the fifth century.

Such a site, furthermore, would be an opportunity to introduce Thucydides' history of the war, at least in excerpted form, a text with both practical and pedagogical benefits. His account, first of all, leads the reader through battles closely enough that their progress can be followed on modern ordinance survey maps; one can still visit the quarries where the Athenian prisoners of war were held captive and died. Secondly, his narrative of the decline in Athenian fortunes after the Sicilian expedition is one of the most riveting stories ever written, and will be able to hold the interest of younger students with relative ease.

> *Our belief is that you have to trust students with the artifacts of the past. And give them the task of attempting to make sense of it. So that the* Archaeotype *program, for instance, is really based in the notion that if you give children access to the artifacts of Ancient Greece or the artifacts of Ancient Mesopotamia or Ancient Egypt that they will, in fact, be able to reconstruct a historical narrative of their own.*—Frank Moretti, Apple's Imagine.

I would very strongly recommend that still more efforts be made to link the study of primary objects to the study of primary texts. The textbooks for students at the middle-school level (to judge by the books I have seen at Dalton and elsewhere) seem generally cursory and dull; until better ones are available, why not use primary sources? I spoke at some length with Mary Kate Brown on my last day at Dalton and together we drew up a list of readings which might be appropriate; they are readily available, and can be revised or excerpted to fit the level of the students. I don't say this lightly; I am aware of how much work is involved in these recommendations, but I think the result would be worth it. The conjoining of archeological material (through *Archaeotype*, slides, museum visits, etc.) with literary and historical texts in a semester-long project on a specific period of Greek history would be productive enough and rich enough to justify the investment of time and resources.

Conclusion

My first favorable assessment of *Archaeotype* has been confirmed by this second look; I am more impressed still by the *Assyrian Project.* Of all the observations and comments above, there is one feature which represents the program's greatest value and promise, and which Dalton has exploited most skillfully and most effectively: *Archaeotype* is a foundation which can be built upon and expanded, which will evolve and grow as new instructors work with it and as new technologies are applied to it. This is, therefore, a program which will educate and challenge not just students, but also, inevitably, those who teach it. The program by its nature encourages and invites teachers to explore familiar intellectual territories in new ways, and to develop new areas of expertise.

* * *

Evaluation of Seventh Grade Geometry Course: Susan F. Jacobs, Coordinator of Mathematics, Science, and Computer Education, Manhattanville College, Purchase, New York

In the late spring of 1993 I visited The Dalton School to evaluate an innovative seventh grade geometry course taught by Dr. Robert Mason. I was generously provided with opportunities to gain information on which to base my evaluation.

Tom de Zengotita, a Co-director of the Dalton Technology Project, provided me with a wealth of printed background information in advance of my visit. While at the school I was able to explore freely, to visit classes, and to interview students and faculty. I spoke at length with Dr. Robert Mason, Chair of the Mathematics Department, and a co-designer of the course. I visited Dr. Mason's class sessions for two days. On each of those days I interviewed groups of students in the library directly after class. I was given to review at leisure a copy of a videotape filmed in the classroom, copies of handouts and assignments given to students, samples of student work, and a written report prepared by Dr. Mason. After my visit I continued to communicate by telephone with both Tom de Zengotita and Dr. Mason to gain additional information.

As I evaluate this course I will address the following:

1. Overview and goals of the Seventh Grade Geometry Project
   a. The changing role of geometry
   b. Geometry in the Dalton curriculum
2. Detailed description of the course
   a. Observations
   b. Specific elements of the course
3. Some further pedagogical issues
4. A look toward the future

Overview and goals of the Seventh Grade Geometry Project

The changing role of geometry

In response to changes on several interrelated fronts, geometry courses nationwide are under review. First, the role of geometry in the fields of mathematics and the sciences is undergoing rapid change. Second, the increasing use of computers in the professions and in the schools offers new potential and makes new demands. Finally, research about how students learn mathematics indicates a direction for changes in the way mathematics in general and geometry in particular are taught.

Until the present time, most students' exposure to geometry has been limited to Euclidean geometry; little changed in over two thousand years. Although newer, non-Euclidean geometries are now more useful to the mathematician and the scientist, a strong case still can be made for the study of Euclidean geometry as a basis for later learning. From this study students traditionally have been expected to learn to use deductive reasoning and to acquire a mathematical notion of spatial concepts. Both are essential to success in more advanced mathematics. Although deductive reasoning also is taught in algebra, a course such as Dalton's new seventh grade geometry course provides superb opportunities for students to develop the ability to relate logical, numerical, and spatial concepts.

> I arrived early for my first visit to the geometry class....Students entered a few at a time. They seemed to know exactly what to do and started to work without any urging....Pairs of students took their places at three of the computers. A single student typed an essay at the fourth....Each student referred to a thick three-ring binder containing assignments and their own work....Almost immediately small groups of students became involved in earnest discussions. Some argued a point verbally, others with a diagram at the blackboard, others at the computer, and still others with pencil and paper. My very first and very startling impression was that these students routinely backed up their statements with reference to "primitives" (relationships demonstrated or proven earlier) or to mathematical principles.

The advent of the computer has begun to revolutionize thinking and learning. Much of modern mathematics requires geometric insight and is represented visually. The availability of computer graphics software has allowed representation and solution of many types of problems that previously were considered too complex to solve. The new mathematics of fractals, chaos theory, and multidimensional analysis are examples of the power of computer visualization. Even at the school level, good geometry graphics software can aid students in exploring the mathematics of space.

Current reforms in education are as appropriate to mathematics as they are to any other discipline. The Dalton Technology Plan supports an atmosphere in which a diversity of questions and ideas is welcomed, discussion among peers is a crucial element in a collaborative learning process, access to materials and resources is uninhibited, and the individual student may influence the pace and direction of exploration. In such an atmosphere, students will not be confined to memorization of the results of other people's exploration of geometry; they will be free to explore geometry themselves. It is in such a framework that the new seventh grade geometry course successfully completes its first year.

Geometry in the Dalton curriculum

It is my understanding that Dalton students currently study basic descriptive geometry in sixth grade, where they learn, for example, the definitions and some properties of geometric shapes as well as how to calculate areas and perimeters. A textbook and work with manipulatives including geoboards complement their study.

The former seventh grade course taught students to look at geometric constructions from three points of view: with reference to a Euclidean model, by means of algebraic analysis, and by observing patterns resulting from numerical measurement. The new seventh grade course is a departure from the former course in method and in scope but not in basic content.

In eighth grade students begin to analyze shapes more formally in terms of points, lines, and planes. They explore such relationships as parallelism and perpendicularity.

Two courses are taught in tenth grade. The first, a traditional course in Euclidean geometry, involves constructions with compass and straightedge and the development of methods of formal proof. The second provides a combination of Euclidean and transformational geometries.

The new seventh grade course is admirably designed to provide for students a meaningful link between the goals of courses that precede and those that follow it. Studies show that informal work in geometry leading to intuitive belief in the truth of theorems is the best preparation for attempting formal proof of those theorems. Students lacking prior intuitive experience are less able to reason with understanding, and must rely on inflexible routines committed to memory. Those students with intuitive understanding are better equipped to use geometric relationships to develop new theorems and to apply them to useful applications. Work with *Geometer's Sketchpad* in Dr. Mason's course provides students with the opportunity to develop intuitive understanding of the relationships that they will later explore formally.

As I will discuss in the final section of this report, some degree of modification in eighth and tenth grade courses may well be advised as the group of students now in seventh grade moves through later grades. Their successful experience with the new geometry course has given them understandings and expectations which may be used to advantage by teachers in the higher grades.

Detailed description of the course

Observations

I arrived early for my first visit to the geometry class, to speak with the teacher, Dr. Mason. Students entered a few at a time. They seemed to know exactly what to do and started to work without any urging. Tables and chairs made a loose ring in the center of the classroom and four computers faced outward at the four corners. Pairs of students took their places at three of the computers. A single student typed an essay at the fourth. Other students gathered in small groups at tables. Early arrivals had first choice of seating and the chance to use a computer. Each student referred to a thick three-ring binder containing assignments and his/her own work, both completed and in progress. Each pair of students was working on a different problem.

Almost immediately small groups of students became involved in earnest discussions. Some argued a point verbally, others with a diagram at the blackboard, others at the computer, and still others with pencil and paper. My very first and very startling impression was that these students routinely backed up their statements with reference to "primitives" (relationships demonstrated or proven earlier) or to mathematical principles.

My second impression was that these students work well together and enjoy their work. They take their discussion seriously, listening well to one another. They thoughtfully refer to statements made earlier, even going back to a previous day.

> The teacher's role was that of guide and coach. Dr. Mason did not lecture... Occasionally he would engage a student or small group of students in extended questioning to help examine obstacles in their thinking. He was very alert to currents of intellectual understanding and confusion, enthusiasm and fatigue, excitement and discouragement, and responded clearly to the students' needs.

One example may serve to illustrate several points. It was late in the school year, and four students were working on a difficult problem having to do with proportion, using both algebraic and geometric reasoning. This group had begun work on the problem in a previous class session. As they entered the classroom, they went straight to work. One had an idea regarding the algebraic work. Another said, "That's what I tried to do yesterday, but it doesn't work." The reply: "Yes it does. Here's how." A reasoned explanation at the blackboard followed, but it did not convince the others. One student commented, "I'm not sure if that's what Dr. Mason said." The reply, "Don't do what a teacher says, do what the proof says." After more discussion, something clicked in one mind, and I heard, "Oh, then I was right yesterday." This was still only a partial solution of the problem. A demonstration by construction on the computer was attempted. New questions were raised: "Does a diameter have to bisect the chord? What happens if the chord is a diameter?" Arguments were given. At length the demonstration was successful. Student at computer, "It works, no matter how I change it, but I'm not sure why." The hour ended here, the argument to be continued.

Several points are clear from this discussion. First, it was clear that challenge excited the students. They went straight to work and continued an abstract discussion for the entire hour. They sustained their work over a period of several days.

The students had learned to use a geometric vocabulary with comfort and accuracy. All were well-informed with the background knowledge needed to solve this difficult problem, and had learned useful strategies for working toward a goal using that knowledge.

Students shared their quest. Each offered thoughts and each was listened to. Diverse personalities shared their advantages. One student was good at generating new ideas, one at doubting them, another at careful weighing of options, another at looking for loopholes. Together they were more powerful than any one alone. All were fair-minded and all used logical argument to back up their statements.

The teacher's role was that of guide and coach. Dr. Mason did not lecture, but his beliefs and goals were made apparent to the students by brief comments or questions made at the right time and the right place. Occasionally he would engage a student or small group of students in extended questioning to help examine obstacles in their thinking. He was very alert to currents of intellectual understanding and confusion, enthusiasm and fatigue, excitement and discouragement, and responded clearly to the students' needs. He is clearly in command of the class, but encourages students to believe that authority, even that of the teacher, does not take away students' right to question in the light of evidence.

Students exhibited flexible and critical thinking. Their focus was the problem itself and the idea of proportionality. While the focus remained constant, the approach was flexible. Students came back to old issues from new directions. They were able to go back and forth between algebraic and geometric aspects of the problem. They listened to different approaches with respect and weighed them on their merits, based on prior discussion. They referred to their three-ring binders to obtain evidence from earlier, related problems.

Students were flexible, too, in their use of media. They moved smoothly from pencil and paper, to blackboard, to computer, to verbal argument, to reference materials, to prior experience, and back to pencil and paper. Each medium was a tool, not a master.

Other groups of students in the class, working on problems at varying levels of difficulty, exhibited similar qualities. Critical and collaborative thinking, openness to alternative approaches to a problem, assimilation of the vocabulary and basic concepts, and comfort with the computer as one of many thinking tools were common at different levels of expertise.

An applied problem, the *Galileo Theater*, required students to optimize seating space in an auditorium, working within certain constraints. Five students worked together on that problem during my visit. They did initial planning with paper and pencil and much discussion. At an intermediate stage, some students were convinced that no solution was possible. After that impasse, they proceeded to come up with some solutions. During my second visit they were transferring their design to the computer for further study and refinement.

Whereas the problem described earlier required demonstration of the *existence* of a set of relationships, this valuable applied problem required creative thinking leading to optimal *use* of relationships. Theoretical problems and applied problems are both important components in a geometry course. Most of the problems in this course are theoretical. Students might benefit from working on an applied problem at the end of each set of theoretical problems, rather than only at the end of the course. Applied problems help students learn some real-world uses of the mathematics they have been studying, and provide opportunity for a different kind of creative, collaborative thinking, enjoyed by most students.

Specific elements of the course

Several components of the course merit particular attention. They include: colloquia, student logs, geometry problems, students' solutions and essays, algebra, computer software—the *Geometer's Sketchpad*, the course handbook, use of library resources, and assessment.

<u>Colloquia</u>. Students use the word "colloquium" or "speaking together" in several distinct ways. The word may refer to a whole class lecture or discussion. Such colloquia occur when the whole class shares a single issue or problem. A small group colloquium may be a brainstorming session, an investigation of an issue, or a discussion about how best to solve

a problem. At other times a group may present their work to the teacher or to another group of students. Even a discussion or argument between two students may be thought of as a colloquium. What all these have in common is that colloquia are dedicated to learning about and thinking about mathematics. Use of the word lends seriousness of purpose to communication. Students are quite aware of their use of talking together as an important part of learning and thinking. They know that when they enter the geometry classroom, their communication will be in the form of colloquia, not just talk. Very few colloquia are formally structured or scheduled in advance. They seem to occur spontaneously as they are needed. Colloquia are essential to the study of geometry in this class.

Student logs. During the early weeks of this first year of the new course, students were asked to keep logs—records of colloquia—in notebooks. As the year progressed, logs were lost. It was decided that logs should be written on the computer and stored in individual student "accounts." The new system worked better. Students' logs were evaluated by Dr. Mason and used by the students to help them study and review. In practice, the greatest value of the logs lay in their creation, when students were forced to put their thoughts into words. Few students reported referring to the logs during the course, except to prepare for a test. Nonetheless, the students felt that they were quite valuable. Log-keeping improves writing and thinking skills. It helps students organize their ideas and remember what they have understood from a discussion.

Geometry problems. The problems form the heart of this course. Not unlike problems in other geometry courses, they have been selected and sequenced carefully to take students from investigation of simple "primitives" or axioms through problems of increasing complexity as new primitives are added and their relationships explored. The concepts are cumulative. Each problem requires the use of concepts explored in an earlier problem. Students work their way through a problem set at different rates. Some difficult problems are skipped for a time and returned to at a later date. The most difficult problem may not be solved by any group of students. At any level of difficulty students are learning to think, to argue in a coherent way, to use a variety of approaches, to broaden their knowledge of algebra and geometry, and to use a variety of media as tools in problem-solving.

I asked a group of students which part of the problem solving process they like best: the beginning, the middle, or the end. The immediate general response was "the middle" because they enjoy discussion and sharing ideas. One student said "the end, because I really understand the problem after I have written up my work and read it over." A third liked "the beginning, because that's when I do most of my thinking—when I have to figure out what ideas I have to use."

Problems are given in sets, to be worked during a time period of from one to six weeks. When questioned about the length of the assignments, some felt that one week was too short for them to get deeply involved. Others said that six weeks was too long. They tended to leave too much of the work until the last two weeks. One student admitted that he was not able to keep track of a set of problems and essays for six weeks without losing the notebook. The consensus was that three or four weeks might be ideal for an assignment. All agreed that assignments need not all be of the same length.

Students' solutions and essays. Students submit sets of problem solutions in the form of illustrated essays. Each solution follows the general form: statement or description of the problem; outline of a plan or argument; description of the procedure followed, sometimes with a list of the "primitives" or axioms used; summary and conclusion. The student work is varied in style. Some students rely heavily on logical argument based on previously proven or demonstrated "primitives." Some use algebraic arguments whenever possible. Some others illustrate and measure several particular cases of the problem using the animation and measurement capabilities of the *Geometer's Sketchpad* to demonstrate what they believe to be the general case. One student began by doubting that the statement to be proven was true. She used a geometry text as a reference and discovered a proof, after which she went on to use computer automation and measurement of figures to satisfy herself that the textbook was, in fact, correct. I commend the teacher for supporting an atmosphere in which such doubting is encouraged.

Many students do not actually prove anything. They demonstrate, illustrate, or discover relationships among properties of geometric figures. Preparing such an informal argument is a very important first step toward learning to build a rigorous proof. These students will be well prepared for formal tenth grade geometry.

The typed essays are accompanied by figures that are either hand-written or computer-generated. Some students use more of the capacity of the computer than others. For example, some use varied fonts and have discovered how to write superscripts and fractions on the computer. Several have learned how to incorporate accurately drawn figures into the text.

In some ways, the notebooks that contain completed students' essays are re-creations of geometry, far superior as learning devices than would be ordinary textbooks. Once a student has proven or demonstrated a theorem, that student may use it to prove others. Students are seen flipping through their very own collected work as they search for support of their arguments. They use only what they have come to believe through firsthand experience.

> In his evaluation of the software, Dr. Mason commented that the incorporation of a spreadsheet would make it easier for students to see patterns in lists of measurements. The designers of the *Geometer's Sketchpad* are now undertaking just such a change. The next version of *GSP* will allow presentation of measurements and calculations in table form. I recommend that Dalton purchase an upgrade of *GSP* when it becomes available.

Students share their reflections in their essays. Often students evaluate the problems in useful ways. "This problem was tricky to animate." "This problem was really easy after doing the one before." "This problem was very similar to number 2.15." "This was, by far, the hardest problem in the packet, but you feel as if you accomplished something when you reach its solution." "We knew that...From this we discovered...Then it hit us....From this problem we draw the conclusion that when dealing with a problem like this, one should always observe the angles, and they may help you find a solution, as they helped us in this case." "This essay has proven the hypothesis given above. It has also explained why it makes geometrical sense." The great value of the approach used in this class is that students learn to make geometrical sense.

Algebra. This course involves the use of algebra new to students, for example, the algebra required to describe and solve proportions. The Heath Pre-Algebra text is used as needed for this purpose. Students benefit from learning geometric contexts for the algebra as they learn it. The geometric and algebraic representations of the concept of proportionality are mutually reinforcing. Some students prefer to use one, some the other, in a problem, but all learn to relate the two, and use one to validate or verify their work with the other.

The computer software—the *Geometer's Sketchpad*. Last summer I attended a conference on "Computers in Geometry Classrooms" sponsored by St. Olaf's College and the National Science Foundation. For four days we discussed the role of the computer in the geometry classroom and weighed the relative merits of more than twenty geometry software programs. It pleases me to state that the *Geometer's Sketchpad* (*GSP*) used in the Dalton program was my first choice as well, because of its flexibility and its power. Its power allows the student to explore widely and in depth. Its flexibility requires the student to do the thinking and make the decisions. Its strict limitation to geometric elements and their relations keeps students on track and focused. Even during the early weeks when Dr. Mason encouraged "free play" so that students could learn to use the software, the students were learning geometry at every step. The world of the *GSP* is the world of geometry, with its definitions, its regularities, and its complexities.

After the initial exploration period, students gradually became more proficient in use of the *GSP* software. Student comfort with the computer was dramatically made apparent when Dalton students acted as tutors for high school teachers at a recent *GSP* workshop. All were impressed with the degree of expertise exhibited by the students.

The use of computers to draw and animate geometric figures is a major innovation in this course. Students continue to draw figures with paper and pencil. There is still great value in that. Here, a comment about accuracy of constructions may be in order. Accuracy in drawing is by no means an adequate substitute for logical argument. Sometimes accurate drawings have a negative effect, when they lead the student to rely on appearances that do not lead to a proof. For example, if two lines appear to be of equal length in an accurate drawing, the student may fail to realize that they must be proven equal. Dr. Mason's students' rough sketches often represent their problems well enough.

Sometimes, however, an accurate drawing facilitates the discovery of relations within a figure, and thus helps the student search for theorems that might be appropriate in a proof. The computer constructions are excellent for this purpose. Formerly, accuracy in construction was a major component of geometry assignments. Students were expected to prepare for mechanical drawing courses. Skill at mechanical drawing is less necessary in the age of computer-aided design. Dr. Mason's course rightly focuses on geometrical thinking, and places a reduced emphasis on accuracy of pencil and paper constructions.

Not only does the computer allow students to produce accurate drawings, it allows students to watch drawings *change*. Students decide which properties in their figures will remain fixed, such as a ninety degree angle, the intersection of two lines at a point, or the length of a line. Other relationships may be animated: stretched, translated, or rotated. Measurements of angles, lines, areas, and arcs are displayed as they change or remain constant under transformation. Intuitive understanding of geometric relationships is thereby greatly enhanced.

For example, a triangle can be deformed so that the base and height remain the same while the angles and sides are changed. By displaying the area measure, students will see that the area is unaffected by changes that preserve the base and the height.

Dr. Mason pointed out that some students fail to accept some of the definitions in geometry. They do not believe that they are true, or they do not believe them in a way that makes them accessible as a basis for thinking. Animation helps students gain intuitive understanding of definitions.

Let us look at one small example. The bisector of an angle divides it into two equal angles. When students use the computer to animate a point on the angle bisector, they slide that point along the bisector. They record the measure of the perpendicular distance to the sides of the angle from each position of the point. They see that the point, as it moves along the bisector, is everywhere equidistant from the two sides of the angle. This experience gives them a deeper intuitive understanding of the nature of an angle bisector.

In his evaluation of the software, Dr. Mason commented that the incorporation of a spreadsheet would make it easier for students to see patterns in lists of measurements. The designers of the *Geometer's Sketchpad* are now undertaking just such a change. The next version of *GSP* will allow presentation of measurements and calculations in table form. I recommend that Dalton purchase an upgrade of *GSP* when it becomes available.

<u>Course handbook</u>. Students were given a handbook at the beginning of the course. In it were guidelines for study and an explanation of the significance of various elements of the course. Some excellent material was included in this booklet, and students stated that they had found it very useful at the beginning of the year. As they became familiar with class procedures and expectations, they needed it less and less. Dr. Mason expects to undertake revision of this handbook to incorporate into it any modifications that he might make to his course in preparation for the coming year.

<u>Use of library resources</u>. I was pleased to see that students have regular assignments related to the history of mathematics. An introduction to the history of mathematics helps students to realize that mathematics is an evolving cultural creation. When students learn how mathematical discoveries and inventions have come about, they learn that mathematics is more than a collection of rules and procedures to be memorized. They learn that

mathematics is created in response to the ideas, needs, and possibilities inherent in a particular time and place.

Dr. Mason's class is encouraged to use library resource materials to investigate important personalities and their discoveries. In addition, students go to the library to find geometry textbooks for background information when working on a difficult problem. Library research does not play a major role in this course, but it plays a considerably larger role than in most geometry courses.

Assessment. Assessment of students' work is based largely on students' written logs and their essays. There have been several tests, and Dr. Mason is eager to develop additional ways to assess students' learning. He has suggested, and I have agreed, that perhaps an appropriate performance test would be to ask students to work one or more problems similar to those which have been the major part of the work of the course. I feel that Dr. Mason has a good sense of the level of accomplishment of his students. He has engaged in discussion and questioning with each of them many times and has read their written work carefully. The greatest value of a performance test might be not its use as an assessment device but, rather, as an incentive for students to review and an opportunity to pull together what they have learned during the course of the year.

Some further pedagogical issues

When a course is radically modified, as was this one, many aspects change; many remain the same. Student diversity, for example, never loses its significance as an issue. In any course some students will do better than others. The learning style of some students will be better supported than that of others.

The learning atmosphere of this class is exciting for most of the students. They enjoy exploration and discovery. They enjoy discussion and thinking aloud. They enjoy recording their work in a printed and illustrated notebook. They enjoy using the computer to assist them in their thinking. They derive pleasure from success as they move ahead through the sets of problems.

The flexible nature of the colloquium allows Dr. Mason to give different kinds of assistance to students depending upon their needs. When a group is moving rapidly but perhaps superficially through a problem, he slows them down with challenging questions. For others, he engages in a one-to-one series of carefully graded hints and prompts to assist over a difficult obstacle. When a group is stymied, he nudges them with a question to move them sideways to a more productive track. His teaching style is varied according to the needs of the students. In spite of every teacher's best efforts, however, students know who is ahead and who is behind in the work. The sequential numbering of the problems makes this perfectly obvious to the class. Of course I realize that even kindergartners understand the difference between "robins" and "bluebirds." It is not necessary to call them the #1 group and the #2 group for them to be able to rank themselves.

But the issue is more than one of rank. Not all students need work on exactly the same path through the problems. Dr. Mason knows the problems and the students so well that he would be quite capable of hand-picking problems for students. If the set of problems were somewhat greater and all the problems were stored on the computer, it would be easy for a student to print out an individualized problem or set of problems. Then a slower student would not always be three or five problems "behind" a faster student. Although geometry is cumulative and sequential in its logic, it is so broad that no student will cover it all. Choices must be made in every case. Those choices need not be the same for every student. Throughout the set of topics the more difficult problems could be the focus for some students and skipped over by others.

> It is important that computer use be integrated into other mathematics courses as this group of students continues to grow.

I noticed that students whose notebooks are somewhat disorganized with pages falling out are also the same students who are somewhat disorganized when working at the computer, getting involved with color choices, for example, instead of working on the problem. There will always be some students who are more organized than others. Perhaps less organized students might benefit from having a chance to select problems on which to work, to assist in the planning of their study. Discussion with the teacher of the relative pros and cons of particular problems might help direct their attention to the learning goals of the class.

Gender differences are of particular interest in geometry. Research has shown that society expects less from girls in mathematics at this age and less from girls in spatial-visual thinking at every age. I am happy to say that the girls I observed at Dalton are able to hold their own in this class and seem to enjoy it. I think it is important that they are encouraged to defend and argue their reasoning in this class. I observed that Dr. Mason spent more time questioning and challenging boys than girls. Perhaps the two days of my visit were not typical, but I hope he will give equal time next year to questioning and challenging girls as well as boys. As a visual thinker and lover of geometry myself, I do not think of geometry as an activity especially for boys.

I asked a large group of students whether they thought girls and boys think differently in geometry—whether they approach a new and difficult problem in exactly the same way. Only boys responded. They notice that girls start typing early in the thinking process. This has led them to believe that "girls just know the answer right away. They start writing numbers right away. Then they write pages of explanations." They assume that because they themselves write later, they must understand later. I was amused to see that no girl offered to refute this assumption! Writing, drawing, constructing, arguing, and quiet reflection all are important thinking processes. All students should be encouraged to learn to use each of those processes productively.

A look toward the future

In its slim volume, *Reshaping School Mathematics* (1990) the Mathematical Sciences

Education Board sets forth goals for mathematics education in a setting which makes use of computers for learning. They state, "Learning to understand and construct logical, coherent mathematical arguments is a major goal of school mathematics... More important than facility with formal proof is an understanding rooted in a variety of elementary examples that mathematical truth is logical and not purely empirical." The new seventh grade course is admirably designed to meet this goal. My reaction to my visits to Dalton was overwhelmingly favorable, in spite of my few suggestions for possible improvement.

As this group of students enters later grades, it is important that they not lose the gains they have made as a direct result of using computers in geometry. In particular, the computer makes the rich and productive connections between geometry and algebra clear and accessible. As a result of this feature, professionals in many fields increasingly use visualization as a mathematical thinking tool. Dalton has the opportunity to prepare its students to be at the leading edge of mathematical activity in their chosen professions, whatever they may be. It is important that computer use be integrated into other mathematics courses as this group of students continues to grow.

In the video clip I was given, a student works on a difficult problem involving proportion. After a series of questions from Dr. Mason, leading the student up the garden path, the student asks Dr. Mason, "Without assuming something, isn't it impossible to solve the problem? If something changes can it still be solved?" This question is one of the fundamental questions in geometry, and presages a breakthrough into new ways of thinking mathematically. The student is finally able to ask the question, but not quite ready to answer it. The computer enables students to visualize change. I would argue that use of the computer has enabled this and other students to tackle deep questions that might have escaped them without it. Perhaps next year, or over the summer, this student will begin to answer the question and move on to others. I would urge, once more, that computers be available to this class, and understand that during the summer Dr. Mason and others will plan a new eighth grade course incorporating computer use. With luck and hard work, that course will be as exciting and as successful as the seventh grade geometry course has been.

* * *

Evaluation of Computers and English—Eighth Grade Project: Judith Rae Davis, Assistant Professor of English, Bergen Community College; Adjunct Instructor of English Education, Teachers College, Columbia University

The Classroom

> The teacher...moves from group to group to help them solve problems, to nudge them in a direction, to scaffold learning, and to nurture exploration. The students also use other experts in the school building as resources. For example, questions about the Latin origin of certain Shakespearean vocabulary are answered when the students consult Dalton's Latin teacher. Likewise, computer questions are dealt with by computer technologists on staff in the building. The important common denominator in all of this is that the students formulate their own questions, and they seek answers.

The physical appearance of the classroom reflects an innovative departure from most English classrooms I've visited. Small groups cluster around four computers that are situated along two sides of the classroom. Conference tables in the shape of a hexagon occupy the center space of the classroom. These are used for whole group meetings, or conferring among pairs or small groups of students who are discussing literature or responding to writing they have done about literature. Significantly, the teacher's desk is outside of the circle and away from the computers, indicating a possible shift in authority in this classroom. The teacher is not *in front* of the class, dominating the students by giving out information, as in traditional classrooms. In this classroom, the teacher appears to act as a learning consultant, a co-learner who fosters, participates in, and facilitates the learning of her students.

> The computers do more than shift the physical focus in the classroom away from the teacher's desk. They facilitate the way learning is done in this class....Students might engage in discussion as a group, and representatives from each learning group are at the computer taking notes for their group....They are like literary critics, annotating their texts as they analyze them.

The class of eighth graders is divided into four work groups of four students each. They are expected to work as a team exploring Shakespeare's *Romeo and Juliet.* Each group decides a working agenda. Some groups divide the work and discuss the results as a group, while others work through the assignment as a committee. Sometimes the groups work on the computers in the classroom, while at other times they are in other parts of the school building—networked by the computers. The teacher, Molly Pollak, moves from group to group to help them solve problems, to nudge them in a direction, to scaffold learning, and to nurture exploration. The students also use other experts in the school building as resources. For example, questions about the Latin origin of certain Shakespearean vocabulary are answered when the students consult Dalton's Latin teacher. Likewise, computer questions are dealt with by computer technologists on staff in the building. The important common denominator in all of this is that the students formulate their own questions, and they seek answers. Their classroom teacher encourages their inquiry and exploration; she does not provide the answers.

The assignments which the students execute also reveal a change from traditional English classrooms. First of all, students are expected to generate their own questions for analysis and topics for writing. "In real life, somebody doesn't give you the questions," Ms. Pollak said. The apparent goal of this curriculum is to get students to ask the questions and then investigate the answers, present them to their peers for discussion and analysis, and write about them in academic essays. What is interesting about these assignments is that they require students to read a text together and to return to the text to revise and reconstruct their ideas in terms of their research and analysis. They are expected to collaborate in their work, as well as write individual academic essays about their reading and analysis.

The computers do more than shift the physical focus in the classroom away from the teacher's desk. They facilitate the way learning is done in this class. All notetaking and essay writing are done on the computers. Students might engage in discussion as a group, and representatives from each learning group are at the computer taking notes for their group. When they meet in groups to read and analyze text, they generate computerized "note cards" which correspond to and act as footnotes to their text. They are like literary critics, annotating their texts as they analyze them. All essays are word processed, so the students benefit from the obvious advantages of composing and revising on a word processor.

Research about the reading is also done on the computer. When questions about the reading emerge, students can use a variety of HyperCard "stacks" to do research about the historical background of a story, various versions of a play, or to get pictures and drawings about costumes or staging devices. They can use the computer to scan through the text to locate repeated references to a common word or theme. For example, one group I observed was interested in the theme of love in Shakespeare's *Romeo and Juliet*. Ms. Pollak suggested that they use the "search and find" device to locate every reference to love in the play. In addition, the networking of the computers enables students to access a variety of resources like *Compton's Encyclopedia* and the *Oxford English Dictionary* to find answers to their research questions.

The most impressive and interesting way the computers were used by students was the connection between the scripts of the play on the computer screen and laserdisk performances on an adjoining television monitor. When students wanted to examine Act II, scene iii, of Shakespeare's *Romeo and Juliet*, they could look at how Franco Zefferelli staged it in the 1970s, how George Cukor did it in the 1930s and how Wise and Bernstein adapted it for *West Side Story* in the 1960s. The comparison of Shakespeare's original to the three renditions of this scene of the play raised interesting and important questions to these readers and sent them to the library, to experts, and to other files on their computers to find answers.

> Students said they read differently than they did before taking this class. One student said she "read deeper," another said he "knew how to analyze better," and a third said it was the first time in his life that he was "so into the meaning" of his reading. When I asked students about how they liked re-reading a text even more than three times, they told me that they were learning *how* to read: "It's not how much you read, but *how* you read it that counts." Students were unanimous in their agreement that this method improved the way they went about reading, and no matter what they read now, they read it better, with a questioning mind.

When writing essays about their reading, students act as peer editors of one another's work. This is beneficial for both writer and editor—the writer gets a more authentic audience than his or her teacher, and the editor gets the empowering position of being able to respond as a critical reader, as well as to enhance his or her own proofreading and editing skills. In general, this is not like the traditional product-centered classroom where students submit essays to the teachers who write in red ink in the margins phrases like "awkward" or "fragment." This drafting and rewriting with student editors empowers writers and resembles the real-world work of writers.

When students finally turn in work for their teacher's evaluation, they use the networked computers to transfer their essays into her electronic file. Ms. Pollak responds to her students' essay via the computer, adding her comments in a different font in the text of the student's essay. She returns the essays to their authors' electronic files, and no "hard copy" of the essays is ever exchanged!

Evaluation

Several theoretical perspectives addressed in recent scholarship on reading, writing, thinking, and learning are evident in this classroom and seem fundamental to the obvious success of these students. It is important in this report to separate the impact of the technology in Molly Pollak's classroom from the outstanding pedagogy that inspires her teaching.

First of all, Ms. Pollak's curriculum reflects a recently renewed interest among scholars in the transactional theory of reading. In the 1969 edition of *Literature as Exploration* (1938) Louise Rosenblatt used Dewey and Bentley's term, "transaction," rather than "interaction" to describe what happens when a reader encounters a text and the "transactional" theory of reader response was born. In 1978, her second book, *The Reader, the Text, the Poem,* refined and augmented the transactional theory of reading set forth in her earlier work. According to Rosenblatt, the role of the reader had been overlooked in previous centuries of theoretical discussion on reading. For years, scholars had written about the importance of the text or even the author in the communication triangle of author, reader, text (1978, pp. 1-3). Envisioning the act of reading as an act of interpretation, like that of a musician whose rendition is guided by a musical score, Rosenblatt sees "the poem" as a performance, the event that happens when the reader makes meaning out of the text:

> The poem, then, must be thought of as an event in time. It is not an object or an ideal entity. It happens during a coming-together, a compenetration, of a reader and a text.

> The reader brings to the text his past experience and present personality. Under the magnetism of the ordered symbols of the text, he marshals his resources and crystallizes out from the stuff of memory, thought, and feeling a new order, a new experience, which he sees as the poem. This becomes part of the ongoing stream of his life experience, to be reflected on from any angle important to him as a human being. (1978, p. 12)

Rosenblatt emphasizes the reader in this transaction. Her theory has been recognized by educators and scholars in the last twenty years, and curricula all over the United States have changed to reflect the importance of the reader. Ms. Pollak's use of small groups to read and raise questions about a text, as well as her use of repeated readings and revision of reading is reflective of Rosenblatt's theory. In addition, the use of groups to read and react to the literature emphasizes reading as an "event" and acknowledges the experiential nature of reading. Since readers, rather than texts or authors, are at the center of the learning process in Ms. Pollak's class, her curriculum reflects important pedagogical theory.

A second theoretical perspective addressed by Ms. Pollak's curriculum is collaborative learning. Considerable research and scholarship have emerged about the value of collaboration and learning in a social context. Clearly, the early work of John Dewey delineates the theoretical advantage to collaborative learning. However, practice in the educational community has strayed from Dewey's ideas in the interests of individuality and competition. In the last twenty years, however, there has been renewed interest in and research done on collaborative learning, especially in the field of English education. Andrea Lunsford and Lisa Ede's book, *Singular Texts/Plural Authors,* and the work of Kenneth Bruffee are continually cited in scholarship and at conferences for English teachers. The simple cliche that "two heads are better than one," or "that it takes two to read a book" have been proven and acknowledged as sound educational practice. Teachers all over are trying to restructure their practice to include group work and methods of collaboration. Clearly, the collaborative learning evidenced in this classroom illustrates its intelligent pedagogy.

A third theoretical perspective addressed by Ms. Pollak's curriculum is writing process theory. Ever since Janet Emig wrote *The Writing Processes of Twelfth Graders* in 1972, a revolution has been going on in the field of teaching writing. Emig proved that *how* a student goes about writing is as important as *what* the student writes, and this insight has sent teachers all over the world back to school to learn writing process theory. In general, this theory acknowledges that writing takes place in stages over time and that we can help students improve their writing by teaching them strategies to facilitate various stages of the process. Ms. Pollak builds writing process theory into her curriculum by encouraging students to generate ideas together, by teaching them to compose at the word processor, and by insisting on peer revision and drafts of their work.

The uses of questioning in learning have been researched for the last twenty years by J.T. Dillon of the University of Chicago. Dillon (1978; 1981) has made convincing arguments that teachers can use questioning to depress student thought. Dillon has described various nonquestioning techniques for teachers to use in classroom discussion. While Dillon asserts that questions are important in the thinking process, he writes "there is no way...to conclude therefrom that the question of one person is functional in another person's thinking" (1978, p. 51). Ms. Pollak's assignments, that call for students to create their own questions about their texts, assure that they are pursuing answers in the direction of their own thinking. Once again, it is evident that Ms. Pollak's classroom is exhibiting sound pedagogical practice.

A final theoretical perspective which underpins the teaching pedagogy in Ms. Pollak's classroom is whole language theory. The separation of reading, writing, speaking, and listening into discrete skills that can be measured and addressed individually is being rejected by current research. Scholars like Kenneth Goodman, James Moffett, James Britton, Frank Smith and others assert the importance of using all aspects of language use in the teaching of language arts. Assignments which ask students to read, write, talk, return to the text, rewrite, revise their reading and writing after discussion, present ideas to others formally and informally, explore hypotheses in reading, writing, speaking and listening to others illustrate whole language theory at its best. Since people need to use language this way outside of school, it seems logical and desirable that schools ask students to use it in the same ways. Whole language theory underpins Ms. Pollak's curriculum and enhances her pedagogy.

The students themselves had great insight into the learning processes that are going on in their classroom. I interviewed students in the course of my observations at Dalton on May 12, 13, and 14, 1993. Students told me that this method of learning appealed to them because they "could work at their own pace." In reality, there are many deadlines set in the course of each assignment. However, since students have to set a course of action within global deadlines, they feel empowered and able to work at a rate they choose. In addition, students appreciated the freedom of making up their own questions, finding the vocabulary each individual student needed to learn, and pursuing theories that interested them.

Students said they read differently than they did before taking this class. One student said she "read deeper," another said he "knew how to analyze better," and a third said it was the first time in his life that he was "so into the meaning" of his reading. When I asked students about how they liked re-reading a text even more than three times, they told me that they were learning *how* to read: "It's not how much you read, but *how* you read it that counts." Students were unanimous in their agreement that this method improved the way they went about reading, and no matter what they read now, they read it better, with a questioning mind.

Students acknowledged the value of the collaborative nature of their classroom. "Everyone helps everyone else," someone said. Sometimes the group structures did not work and other times they were very helpful, according to the students. It depended on who was in the group and the dynamic that developed in each group.

All students agreed that the single most important asset to their class was their teacher. Her enthusiasm for their learning and her ability to direct them without telling them the answers inspired most of these students to love reading and to see learning as inquiry.

In order to assess the impact of the technology on the curriculum, I asked the students to imagine their classroom with the same teacher, same assignments and group work, but without the computers. What are the advantages and disadvantages of the computers in this learning experience? The students recalled a week in the course of the school year when the computers were down, and they remarked that their work ground to a halt. The students expressed the idea that "they couldn't go back" to an English classroom without computers. The pace would be too slow. Students said they could move at a faster pace with the computers, leaving more time to learn other information. For example, if they wanted to find out something about the Globe Theatre, they could pull it up on the screen of the their computer rather than have to run to the library and hope the books about the Globe were not signed out by another student. The computer is faster, more efficient, and more equitable.

The general perception among the students with whom I spoke was that the computers were fun to work with, and that is of great value to eighth grade students. "People our age like hands-on things; we like to push buttons," one student said. It is possible that this perception results in more time on tasks and greater motivation to develop ideas or pursue inquiries.

> ...projects that involve technology like this one present an equity issue. Students, like the one mentioned above, who do not have access to computers at home are at a disadvantage.

Writing is easier on the computer. Most students agreed that they could write more quickly and make corrections more easily with the use of word processing. Students said they had more pride in the finished product when it is word processed because it looks better. Like younger writers using word processors at Dalton, these eighth graders expressed the opinion that handwriting is messy and difficult, and they found that composing on the computer helped them write longer texts and to write them neatly. Students even liked the idea of writing notes on the computer.

Only one student expressed any reservations about the technology. Since she doesn't have a computer at home, she must do most of her work in school. She felt that it was difficult for her to combine learning about computers with learning English. "It was just another thing I had to learn when doing English," she told me. While she admitted that using the computer was getting easier, she still maintained that she did not like the computers as much as the others in two classes I observed.

As I observed, I looked over students' shoulders at notes that they wrote in response to their reading. I was impressed with the many ways in which they decided to organize their notes. As their reading of the play grew and was revised, they created categories in their notes. For example, early notes on the play include plot summary and vocabulary. Later, as students reread each scene, they added in themes, metaphors, and ideas about character development. In addition, students kept track of questions that they had about their reading. All of these notes worked to help students design their own essay topics.

The essays which I examined were superior to work that I have read in college-level composition classes. I was especially impressed with students' ability to cite their texts and analyze them. Citation and analysis are the crux of all academic discourse and these young students are mastering skills that will facilitate their pursuit of higher education. This writing is the outgrowth of the close reading and critical thinking that characterize this curriculum. Essays were well-organized, coherent, and well-documented. The close analysis of citations, including references to historical allusions and metaphorical interpretations, is very sophisticated. More importantly, essays I read were interesting. They were written in response to authentic questions that students wanted to answer. When students write in response to self-generated topics, they work harder and the products are better.

One student proudly showed me the computer video presentation his group made as a result of their study of Salinger's *Catcher in the Rye*. Students assembled pictures of historical sites in New York at the time of the novel, wrote text about their reading of the book, and analyzed the plot and characters in comparison to another adolescent novel, *A Separate Peace*. This type of project involves all the skills of academic writing as students present their analyses on the screen, in addition to the technological skills of creating a visual presentation. There is no doubt that the technology has enhanced the traditional academic writing skills of these students while at the same time pushing them further along the continuum of critical thinking and learning than traditional eighth grade English programs that I have observed.

Recommendations

This project is strongly anchored in theory and wonderfully executed in practice. An evaluation of such a complex project about *learning process* in a three-day visitation is necessarily limited. However, some recommendations can be suggested.

First of all, projects that involve technology like this one present an equity issue. Students, like the one mentioned above, who do not have access to computers at home are at a disadvantage. A limited number of portable computers might be borrowed or rented by students on a yearly basis, much as students rent or borrow musical instruments. With home access to the technology, the difficulties expressed by the student above would be eliminated.

Secondly, teachers, like Ms. Pollak, who are involved in projects like these can be trained as teacher-researchers, or to use Lawrence Stenhouse's term, action researchers. This is particularly justifiable in the case of The Dalton School and the projects undertaken by The New Laboratory for Teaching and Learning. According to one memorandum about The Dalton Technology Plan, students involved in the projects "will need to become skilled explorers, not docile learners: teachers will become, not masters, but native guides, like Virgil to Dante, interpreting, elucidating, cautioning, exhorting." The concept of education as enquiry is basic to the stance adopted by the teacher-researcher. Stenhouse writes:

> The connections between the philosophy of John Dewey and Dalton's founder, Helen Parkhurst, and the resurgence of interest in transactional reading, writing process, critical thinking, and collaborative learning are interesting in light of the work going on in Molly Pollak's classroom.

"To call for research-based teaching is, I suggest, to ask us as teachers to share with our pupils or students the process of our learning the wisdom which we do not possess so that they can get into critical perspective the learning which we trust is ours" (1983, p. 113). The perspective of the teacher-researcher is one of explorer and learner. The teacher investigates the learning with his/her students. In order to evaluate learning *processes*, like the ones in place in Molly Pollak's classroom, a stance of classroom researcher and system of inquiry might be helpful.

Ms. Pollak could research her class from a variety of perspectives. First of all, in evaluating the reading aspect of the curriculum, she might want students to perform periodic reading protocols, which are taped, transcribed, and kept for comparison. These protocols might give insight into students' reading processes as well as indicate the effects of this reading approach. Since students were so enthusiastic about the fact that their reading style has changed, it would be valuable to demonstrate this in some way. The entire research community would be interested in how this inquiry-based approach has affected students' reading. In addition, journals of responses to the reading are wonderful student artifacts to study the learning processes that occur in a classroom of this type.

Secondly, to evaluate the writing component of the curriculum, Ms. Pollak might want to administer periodic writing samples or create a cumulative file of student work to examine their progress over time. In addition, students of this age are able to comment about the metacognitive aspects of writing on a word processor. Therefore, interviews, surveys, and discussions about how their writing process has evolved over the course of the school year would be interesting.

Thirdly, the value of group work might be examined by designing surveys about students' attitudes about groups, asking students to write process logs about their collaborative experiences, and taping the interchanges that occur in small and large group discussions.

Finally, the impact of the technology could be monitored by teaching a reading early in the year without computers to one class and with them to another group. Comparison of student artifacts, responses to the learning situation, discussions, and teacher observations would be helpful in documenting the effects of computers in this classroom.

Teachers can obtain training as action researchers by taking graduate courses in education or by reading recent scholarship in the field. An alternative approach might be to enlist a consultant to mentor teachers involved in projects like this one as they develop a research design, collect and analyze data, report on the research findings, and develop new research strategies as the process evolves.

The connections between the philosophy of John Dewey and Dalton's founder, Helen Parkhurst, and the resurgence of interest in transactional reading, writing process, critical thinking, and collaborative learning are interesting in light of the work going on in Molly Pollak's classroom. It is fascinating to this observer that the impetus of new technology returns Dalton to the original Parkhurst plan of the "lab," enabling these students of the 21st century to explore and inquire as did their predecessors early in this century.

References

Bruffee, K. (1984). Collaborative learning and the 'Conversation of Mankind.' *College English 46:* pp. 447-468.

Dillon, J.T. (1978). Using questions to depress student thought. *School Review*, November issue, pp. 50-61.

Dillon, J.T. (1981). To question and not to question during discussion. *Journal of Teacher Education 32:* 6, pp. 15-20.

Lunsford, A. and Ede, L. (1990). *Singular Texts/Plural Authors: Perspectives on Collaborative Writing.* Carbondale, IL: Southern Illinois University Press.

Rosenblatt, L. M. (1938). *Literature as exploration.* New York: Appleton-Century.

Rosenblatt, L.M. (1978). *The reader, the text, and the poem: transactional theory of the literary world.* Carbondale, IL: Southern Illinois University Press.

Stenhouse, L. (1983). "Research as a basis for teaching". In Rudduck, J. and Hopkins, D. (Eds.), *Research as a basis for teaching* (1985). London: Heinemann Educational Books.

The explosion of interest in hypermedia among teachers of literature, already remarked in Volume I, is due in part to the capacities of the *Playbill* software. The intellectual value of the technology is especially apparent to a seriously educated reader, accustomed to surrounding a text with critical and historical references. The armature of *Playbill* in effect concretizes capacities which scholars have always possessed abstractly. But now, the fundamental process of reading critically becomes a manifest feature of literary education at every level.

***

Evaluation of the Tenth Grade *Playbill* Project: Joseph C. Voelker

Introduction

Almost exactly one year after my first visit to The Dalton School, I returned to observe new developments in the evolution of the multimedia *Playbill* unit in the tenth-grade English curriculum, and to note its broader integration into the high school literature program. I interviewed one working group from each of Mr. Bender's and Ms. D'Aiutolo's tenth grade classes. I spoke with virtually all members of the Dalton English Department, but especially Messrs. Johnson and Glassman, who are also introducing HyperCard technology into their classes. I visited and led discussions of *Macbeth* in both Mr. Bender's and Ms. D'Aiutolo's tenth grade sections, in order to gather impressions of the degree of critical mastery the students had achieved as a result of their reading, class discussions, and *Playbill* research. I read a number of sample papers (and viewed one student-produced videotape). Also, Mr. Glassman and Mr. Johnson gave me tours of their HyperCard projects on *The Russian Novel* and the *Bible* respectively. Finally, I spoke with Ms. Sheridan, Divisional Director of the High School, in order to gain institutional perspective. I found the level of enthusiasm much higher, and the level of frustration much lower, in every cohort concerned, than they were last year.

Two general tendencies were clearly in evidence:

First, I noticed a seasoned realism in the teachers' expectations of *Playbill.* This year they see it primarily as a remarkable research tool, rather than as a "teaching machine." In education, there is always a certain mysticism about new technology, a pious hope that somebody will invent a machine capable of doing new but indefinable things for students' ability to think. The Dalton teachers clearly see, alongside *Playbill's* power to bring other texts quickly to bear, its capacity to foster cooperative work in a compatible group of students. This year, however, they are better judges of its pedagogical possibilities and limitations.

> ...the pioneering presence of *Playbill* has begun to engender other ingenious uses of HyperCard technology that will evolve rapidly. These new projects will take their place in a reasoned sequence from ninth through twelfth grades. This sequence will render students more computer literate in easily assimilatible stages at the same time that they become better researchers and critics who are skillful at contextualizing what they read and learn.

Second, the pioneering presence of *Playbill* has begun to engender other ingenious uses of HyperCard technology that will evolve rapidly. These new projects will take their place in a reasoned sequence from ninth through twelfth grades. This sequence will render students more computer literate in easily assimilatible stages at the same time that they become better researchers and critics who are skillful at contextualizing what they read and learn.

Classroom Atmosphere

Highly motivated tenth-graders coming to *Playbill* with little experience of graded group work are naturally going to be anxious. Collaborative learning—and learning to collaborate—are worthy goals. Last year, however, between technical difficulties with creating textual "links" and inequitable levels of effort among students, some students felt trapped in their groups. Those who were more responsible resented group members who were willing to be carried through the project.

In their testimony, students revealed a grasp of dramatic structure that is probably the consequence of being able to move around the play via word searches and bring up videos on the screen. Students in both Ms. D'Aiutolo's and Mr. Bender's classes spoke about the architecture of the play: the way Shakespeare had to be aware of how each scene supports those before and after it as well as being itself microcosmic of the larger theme of destiny. Likewise, students retained and understood directorial decisions—especially the cutting of scenes—on the part of Welles and Polanski.

This year, I witnessed a greater flexibility and more inventiveness on the part of the teachers, who are themselves far less anxious about the introduction of the technology and much more knowledgeable with respect to its larger potential.

One problem which remains, and to which both teachers testify, is that of the management of time. *Playbill* assignments require that students be competent at reading, not only Shakespeare's challenging language, but also the language of film. In addition, beginning with the *Oedipus* project, they must confront literary critical language as well. And, obviously, they must learn to use the technology in an intellectually rich way. How to provide enough time, and where to devote it, remains a formidable challenge.

Ms. D'Aiutolo's assignment structure provided for (1) reading of the play and viewing of two film versions, (2) traditional class discussion of Act I, (3) small-group exploration of *Playbill* for research in preparation for (4) group presentations of chosen scenes, and finally (5) a formal paper of 3-4 pages, to be written either individually or collaboratively. Ms. D'Aiutolo allowed the formation of the final thesis to come from the student, without delimiting it, although the sample papers I read did come out of topics she had suggested. One of her groups videotaped an interview with the Macbeths, based on a "reality-television" format. By scripting in outline in advance, they achieved a charming balance between spontaneity and thought-out conclusions. (Midway through the interview, the host introduced a "surprise guest," the ghost of murdered Banquo, whose appearance precipitated a difficult social situation for the Macbeths. The acting here was delightful.)

Mr. Bender, responding to the unsynthesized nature of some of last year's projects, provided a finite array of choices for inquiries which he already knew *Playbill* could support. Thus his groups took up scene-based projects such as "The Witches' Scene as Microcosm," and "The Banquet Scene and the Decay of Social Order." To facilitate student thinking about these scene-based issues, he devoted class time to a discussion of realism vs. expression (which anticipated student comparisons of Polanski and Welles), and he invited the director of the Dalton production of *Macbeth* to discuss scene design and the actress who played Lady Macbeth to demonstrate the range of interpretation possible. He also allowed students to work individually where group chemistry wasn't right. When one of his groups failed to come to agreement about their conclusions, he invited them to videotape a debate in which they aired their conflicting views.

While these two teachers approached the solution to *Playbill*'s pedagogical problems differently, they both succeeded wonderfully in integrating the technology into the curriculum, reducing conflict and anxiety of a nonproductive nature, and introducing students to collaborative work and computer use.

I was very impressed in my classroom discussions with both sections. I asked students to make connections between what the witches are "cooking up" and what gets "served up" in the banquet scene. I asked them to range over the play in order to explain metaphorically the presence of a fetus in the witches' pot. This question required them to have quick and thorough mental reference to the entire text, and to be able to synthesize critical ideas at a very high level. For instance, I asked them to see the ritual feasting as an affirmation of communal solidarity, to see Macbeth's feast as broken—an interrupted sacrament—and to connect the witches' culinary activities as a demonic antithesis to the communal ideals symbolized in the idea of a banquet. Their mental agility easily equaled that of my nimbler college freshmen. Both sections were able to pursue the question, one ferociously bright young woman even anticipating its direction by several steps. It is proverbial in educational circles that a good class discussion does not result from the teacher asking students to guess what is in his or her own head and pretending that such a game constitutes conversation. On the other hand, I found these tenth-graders so mentally active and independent-minded that I suffered minor waves of apprehension as I listened to the more active participants begin to weave their own sets of connections. (Some of these webs would have been fascinating, others were too far-flung.) A teacher should respond honestly to what a student makes of a question, but I feared at times we would go off into several directions at once. With a little forcing, I persuaded them to connect the motif of children in the play to the theme of community, and thus to settle on an explanation for the fetus in the cauldron. I noted considerable skepticism on some faces. (Several students had objected earlier that the witches were not brewing their potion in order for someone to eat it, and thus the connection to the banquet was tenuous.) There was a lively sense that, if we had more time, several students would have picked several more holes in the thesis.

In their testimony, students revealed a grasp of dramatic structure that is probably the consequence of being able to move around the play via word searches and bring up videos on the screen. Students in both Ms. D'Aiutolo's and Mr. Bender's classes spoke about the architecture of the play: the way Shakespeare had to be aware of how each scene supports those before and after it as well as being itself microcosmic of the larger theme of destiny. Likewise, students retained and understood directorial decisions—especially the cutting of scenes—on the part of Welles and Polanski. They talked about not only staging and acting, but also cutting of the text, as part of a director's interpretive work. They seemed to be aware

Critical Essays of Macbeth are background to images
from various performances of the play

of this dimension as rather high-order analysis, and to enjoy it.

The Playbill Software

There are numerous developments in the program from last year. *Playbill*'s platform is now constructed in HyperCard technology, with the result that referencing is simpler and faster. (Some students still expressed a wish for a faster chooser.) Linking is now done by word identification rather than number of characters, so revisions or changes in text don't lose key links. There were, however, complaints that during peak times of the day, the program slows down.Although students see both versions in their entirety on laser disk, *Playbill* now displays key scenes from the Roman Polanski and Orson Welles productions of *Macbeth* in a HyperCard window. The teachers chose these scenes from those most frequently referenced on laser disk by last year's groups. The unwieldy and time-consuming process of physically inserting a series of laser disks in a separate player is thus obviated, although students still have access to that technology for less frequently referenced scenes if they want them. *Playbill* now has a much improved selection of really helpful scanned critical articles. These can be word-searched for topical reference, or printed in hard copy to be read in their entirety. There is also a 200-page bibliography with brief annotations that identify their subject better than titles alone. I objected last year that the critical library was increasing in size but lacked rational ordering and selectivity.

> ...students I interviewed commented that the reality of working in a group leads to a sense of the indeterminacy of a text—some of them do seem to understand that the nature of their argument is the same as that which goes on between professional interpreters. On the other hand, just about all students were able to cite how a production of *Macbeth* is an interpretation, just as a critical reading is. They were able to contrast Welles' from Polanski's "readings" in critically interesting ways.

This year, students seem to be finding and using the critics to better effect, but I have the impression from my conversations with students and from one sample paper that students do not voluntarily consult the literary critical articles, and are still in need of considerable guidance from the teacher in understanding what they read. The teachers in the unit are right to require the use of critics, rather than to rely on students to use them voluntarily. They might want to increase their required use slightly. I find an assignment that asks for a comparison of one film version with one critical essay to be intriguing. (At present it is an option for Ms. D'Aiutolo's students.) Such a comparison offers rich intuitive lessons in what constitutes an "interpretation."

Sequencing

Playbill has fostered other HyperCard units in the department, and one can see the pieces of a puzzle coming together. Ideally, Dalton students will, in the future, be introduced to the technology in the Middle School, and move from closed to more openly framed programs. Younger students using programs such as the archeology unit should be solving puzzles whose entire solutions are available in a fairly limited HyperCard realm of possibilities. Then, with mastery of the necessary manipulations, students should be led to undertake complex interpretive tasks for which there is no one right answer, and for which the idea of "authority" is thoroughly problematized. In other words, in the earlier grades, the maze has a solution, in the later, what the machine really contains is an open interpretive debate. By the time they are seniors, students should be able to approach an interpretive question of a Dostoevsky novel having learned that neither the teacher nor the translator nor the literary critic possesses the final explanation. The speed and breadth of access to relevant research materials that such programs as *Playbill* provide facilitate the learning of this complex and sophisticated lesson.

Student Reaction

Students this year expressed no sense of being guinea pigs. They were far less concerned that their grades somehow depended upon the performance of group members less capable or less reliable than themselves. There was an array of opinion concerning the perceived difficulty of manipulating the computer. Some students have clearly stayed away from computers, and for them the software was intimidating. Others were veterans, and complained that the architecture of the HyperCard system could be better designed to allow them faster access between areas. (The teachers are also examining students on their computer skills to be sure that the computer-shy are not letting other people's fingers do the walking.)

In response to their grousing about the technology, I found myself reminding them of just how much is at their fingertips in *Playbill,* compared to the work involved in stepping through the door of a library, where the reference volumes are in one place, the Shakespeare criticism in another, and the videotapes in a third, and where somebody may have taken any of these materials out. (In *Playbill* article's are available for printing out at all times.)

Because of a period of excessive demand for the computers earlier in the year, Ms. D'Aiutolo's class had been obligated to do their searching during the Oedipus unit "by hand"—and it is only fair to say that they were most appreciative of the technology when they finally got to use it for the *Macbeth* unit.

In relative terms, HyperCard study is amazingly convenient, and will undoubtedly cause students to undertake research and contextual study much earlier in their academic careers. It is heartening to think of a future in which college freshmen expect to undertake such study, and are trained in its intellectual modes.

Necessity still dictates the existence of collaborative groups for *Playbill*, simply in consequence of the limited number of computers. This year, students' complaints about their groups were not only milder, but more interesting. Students observed that they disagreed frequently in their groups, but I discovered that these disagreements were often about the meaning of the play, or how to compose good English prose. This order of disagreement is to be encouraged, as it constitutes intellectual debate that is not teacher-centered, precisely what Dalton wishes to foster.

Interestingly, students I interviewed commented that the reality of working in a group leads to a sense of the indeterminacy of a text, and some of them do seem to understand that the nature of their argument is the same as that which goes on between professional interpreters. On the other hand, just about all students were able to cite how a production of *Macbeth* is an interpretation, just as a critical reading is. They were able to contrast Welles' from Polanski's "readings" in critically interesting ways.

Student Work

Ms. D'Aiutolo ordered this spring's *Playbill* unit by first having the class see both the Polanski and Welles cinematic treatments of *Macbeth.* Then she had the class read and discuss Act I of the play in a traditional classroom approach. Then she divided the class into groups of three students at each computer work station and encouraged them to "EXPLORE on your own" by comparing and contrasting critical and/or cinematic interpretations of specific scenes. Students were encouraged to choose among the witches, the setting (heath vs. castle), the initial depiction of Lady Macbeth, and the relationship between Lord and Lady Macbeth, or to devise a topic of their own. They then researched their subject using the Text Browser, to uncover imagery chains in the text and discussions of motif in the literary criticism. Ms. D'Aiutolo urged her students to pay close attention to detail in their examination of differences between the film versions.

After time set aside for preparation, each group had a class period to "teach" their scene to the class, and then they wrote up their findings either as an individual or as a collaborative paper. In reading these papers, I noted an inevitable range of quality. I will take the papers dealing with the witches as an example. All, it seems to me, made valid and interesting observations, noting how Welles stayed closer to Shakespeare's actual stage directions and the written text. They noted that, by placing the witches on a cliff, Welles implicitly gave them a symbolic power of surveillance, a sense of god-like powers of causation as well as foresight. They noted that Polanski, by keeping the witches closer to ordinary human form, and by setting the scene on a beach, diminished their powers in comparison. Two papers noted the suppression from both film versions of the "chestnut scene," wherein the witches acknowledge that their powers to act directly upon the world are limited. These papers speculate well on why a filmmaker—in search of rapid narrative pace—would glaze over this important moral technicality. As with the other papers I read (discussing Lady Macbeth, and the relationship between the Macbeths), the superior papers distinguished themselves on two bases: conceptual clarity, a confident ability to stay focused on what is important, and verbal dexterity, the mastery of a sufficient vocabulary to avoid awkward circumlocutions and inappropriate phraseology. Interestingly, I found that the strongest paper of the entire sampling was composed collaboratively. It discusses the sleepwalking scene (Act V, Scene i). Its conclusion seems to me a model of analytic work, because it demonstrates the effects of careful close reading, and it displays an admirable awareness of dramatic structure:

> "To the casual reader [Lady Macbeth's] dreams are distorted and confused. However, each sentence the character uttered refers to something different in the play. The

events to which they are referenced can be recalled when the text is studied in greater depth. This scene is not only used to recall the past but it carries a warning of Lady Macbeth's suicide. Thus Act V, Scene i (otherwise known as the sleepwalking scene), serves two purposes. It is a reminder of what has happened thus far in the play and it is a premonition of what will soon come to pass."

I should also add that in both Ms. D'Aiutolo's and Mr. Bender's classes, peer editing was an obligatory part of the writing process. It occurred inevitably in collaborative projects, but individual authors also were required to submit their work to their classmates. Mr. Bender employed a questionnaire to ensure that students critiqued their peers' work with serious attention to detail. In order for peer editing to be effective, it was necessary to allow students opportunities for revision. In Mr. Bender's class for instance, after the second submission of the project, some students came forward and asked for a third opportunity to revise, which they were given. If students learn in tenth grade that all good writing is rewriting, they have every chance to establish good habits of composing well before college.

In reading papers from Mr. Bender's group, I noted a similar range of quality. In their final revised form, the best of the papers on the staging of the witches' scene in Polanski and Welles achieved a very high level of judiciousness and incorporated an impressive amount of detailed observation. This paper argued that the realism of the Polanski version, eschewing the high dramatics of the Welles, reduced the witches' power in such a way that it emphasized the human freedom of Macbeth, giving him a humanity that students found recognizable. I also examined several papers from Mr. Bender's section concerning the role of setting as well as costume and acting in establishing the degree of influence of Lady Macbeth over her husband. These observed that the presentation of Inverness as a place of nature, replete with farm animals and a sense of burgeoning life, along with the youth and prettiness of Lady Macbeth, contrasted strongly with Welles' wild psychodrama, and, again, humanized the Macbeths and intensified the tragedy. It is interesting that students of this decade respond more powerfully to a human Lady Macbeth, and less to a version of her as psychic projection, or she-demon. These papers were uniformly good, the best of them was truly impressive.

New Projects

Mr. Johnson's *Bible* unit provides two translations with scanned images of great paintings on Biblical themes. It also provides notecard space for students to enter their analyses of how image and text illuminate one another. The unit invites students to make high-order interpretive connections while it introduces them to a limited array of computer manipulations that they will use again in the *Oedipus Rex* and *Playbill.*

Henceforth, tenth graders will study *Oedipus Rex* in HyperCard prior to their engagement with *Playbill.* The *Oedipus* project provides two translations of the play for comparative study. It also presents one complex critical article that students summarize and respond to, so that they have a guided first experience of the uses of criticism. (They also read portions of Aristotle's *Poetics*, an excellent place to start when teaching young students what literary criticism is.) Students then do an image search, using the Text Browser, that displays vividly how dramatic language repeats motifs in the manner of musical composition. It was evident that the tenth graders in Mr. Bender's *Playbill* section had benefited from their prior exposure to the *Oedipus* unit. Next year's tenth graders will have used both the *Bible* Project and the *Oedipus* unit when they come to *Playbill.*

Mr. Glassman's Russian Fiction unit offers the text of *Crime and Punishment* with critical and historically contextual materials that provide the opportunity for cultural comparison. It provides advanced students the opportunity to confront the most difficult spiritual paradoxes of the nineteenth century, by placing Dostoevsky's masterpiece at the center of the era's radical redefinition of the self.

Recommendations

Mr. Bender offered one of his groups the opportunity to make a video of their conflicting interpretations of *Macbeth.* As an experiment, the *Playbill* teachers might ask all their groups to script carefully in outline and then produce videotapes in the format of *Washington Week in Review* or *Meet the Press* or *Wall Street Week.* Students should submit script outlines in clean typed form, for prior teacher approval. The video clips should have a tight time limitation. (I recommend 15 minutes.) One of the *Playbill* groups produced a video interview with the Macbeths that was intelligent—and I think pioneering—but too long. The ease of the video format can lead to self-indulgence, and Dalton students would do well to learn intellectual discipline in the use of electronic media.

It seems appropriate that a *Playbill* study should culminate in (1) a performance, and (2) a debate. Theater and multiplicity of interpretation are the heart of the matter. The video solution also provides a means of keeping the groups together, while avoiding the squelching of individuality.

Conclusion

Doing away with the collaborative "paper" has reduced anxiety. Better sequencing within the *Macbeth* unit (including four weeks of class discussion) as well as outside it (the prior *Oedipus Rex* unit) has helped as well. The proliferation of interest among members of the English Department is heartening. This year, I saw increased intellectual quality, a clearer conception of how to integrate machinery into humanistic study, and more options between collaborative and individual work. It is important to keep in mind that convenience will allow a person to do a thing that inconvenience will impede. People will go to a place and settle down there simply because a road led to it. Only the rarest of us will leave the road and march off into the underbrush. The computer builds a road when it puts comparable phenomena instantaneously before our eyes. Because it is easy to compare them, we do so.

Largely because of the unwieldiness of library work, secondary education has not traditionally taught the modes of thinking that prepare students to become researchers. I believe Dalton is creating a curriculum that will allow its students to form the habit of being curious.

***

A Formative Evaluation of the Multimedia Architecture Program: Keller Easterling, Professor of Architecture, Columbia University, Parsons School of Design and Pratt Institute

Architecture, Advanced and Beginning Courses

This evaluation was completed after observing Rob Meredith's Advanced Architecture classes and conducting interviews with him and Jeff Dvi-Vardhana, Jefferson Han, Abby Rowe, George Soo, and a number of other students in the advanced class during the week of May 10th, 1993. I also toured the Multimedia Architecture Exhibit on Tuesday, April 27th, which displayed work from beginning and advanced classes as well as senior projects.

> This evaluation compares a secondary school program with the highest standards of university level studios. The question remains concerning how the architecture course might be developed: is it a discipline which involves its own broad exploration and renders its owns artistic growth or is it more specifically defined as an introduction to existing architectural notions and 3D computer modeling? Since this is the first year of the architecture program's new incarnation with computers, perhaps this is an appropriate time to ask that fundamental question.

Tom de Zengotita provided me with materials describing the goals of The New Laboratory for Teaching and Learning as well as with the first Annual Report and a videotape entitled *The Dalton Technology Plan*. At Dalton, computer technology has been used to develop studies that encourage an expansive view of information and allow that information to be accessed through a nonhierarchical, cooperative structure. In so doing, the New Lab takes advantage of natural patterns of curiosity in research. As this written and video material demonstrated, the curricular structure of the New Lab has elicited praise from many. I join in praising it and its supporters. The technology is already part of our students' lives, but Dalton has had the foresight to grow with the changing technology and to access professional expertise and information sources beyond the school environment.

By offering architectural studies at all, Dalton is making an important curricular move—one rarely encountered at secondary school level. These studies are interdisciplinary and engage knowledge learned in the various arts and sciences within a laboratory that puts that knowledge into practice. Because I was so impressed by the Dalton School architectural studies, it seems appropriate to evaluate them within the context of the most challenging criterion expressed by the New Lab program. In this evaluation, I will make a comparative discussion of the Dalton School curriculum and a diversified architectural studio training which is usually found at the university level.

The following outline summarizes my evaluation:

I. Overview

II. Changing Trends in Architectural Pedagogy

III. Comparative Evaluation of the Architecture Program

A. Subjective Exploration
B. Conventional Drawing Skills
C. Structural Modeling
D. Formal Composition
E. Perceptual Drawing
F. Light
G. Site
H. Precedent
I. Teacher/Student Dialogue and Inventing New Programs for Architecture

IV. Summary and Conclusions

I. Overview

With Dalton's introduction of computers within disciplines which use readings and lectures as the primary learning tool, learning becomes discovery and experience in a much more effective way than the classroom could previously offer. But architectural training has always been a somewhat different process. Though confined to the studio, it has traditionally strained to simulate real world experience through a variety of methods which now fortunately include the computer. Since the architecture studio itself already begins to dismantle the traditional classroom situation, the discipline requires a more focused discussion. Can the Dalton School program encompass all of the concerns one traditionally finds in an architecture studio? Can it help to develop a new kind of spatial perception that contributes to architectural pedagogy and to the discipline as a whole? Is architecture a discipline which might serve as a base for a larger set of interdisciplinary investigations which cross reference architecture with other cultural studies? To borrow a phrase from some of the stated goals of the project, can the architecture program make "new wine in new bottles?" Or should goals be more modest at the secondary school level, geared towards a three-dimensional modeling studio influenced by architectural thinking? Without straying beyond the boundaries of the stated goals of the New Lab as whole, some of these formative questions will surface within the evaluation.

II. Changing Trends in Architectural Pedagogy

Though it is difficult to describe the "traditional" architectural studio, there are long-standing practices that are vaguely associated with a beaux-arts tradition which have persisted as the underlying order even of its counterpart in modernism. The thinking is characterized by object making, the primacy of Cartesian space and a reliance on orthogonal projections as the basis of both documentation and design method. In the worst cases, this tradition has been accompanied by a hierarchical view of the studio as instructed and exploited by a "master."

However, at its best, a studio is much less hierarchical than a typical classroom. It is an exchange which operates by dialogue between instructor, student and outside critic and relies on the tools of a number of disciplines. Current critical thinking about architectural pedagogy acknowledges the discipline's potential as an art form that grows into time and experience and also seeks to overcome the inadequacy of traditional architectural media to simulate that experience. Diversified tools are employed to discover new areas of spatial exploration previously obscured.

What follows is an outline of some current thinking about architectural pedagogy. It will serve as a basis for comparison with educational techniques now being developed at Dalton.

Typically, architectural training begins with a subjective exploration to access the student's own spatial experience: the basis of a personal project and the raw material of changing perceptions within the discipline as a whole. Modeling and drawing serve abstract explorations of space and materials which lie outside of a received architectural language. The work is often interdisciplinary, but distinguished from the other visual arts through measuring, scale, ideas of inhabitation and the presence of gravity. Conventional drawing techniques such as orthogonal projections, structure and materials are introduced at the outset of an architectural education.

Typically, exercises in composition begin a discussion of form, but in the best of situations that discussion is complicated by issues of perception and experience. Architecture is not seen then as an object which is fashioned to be "looked at" but rather to be perceived in experience, movement, interiority and changing conditions of light. Light and the warp of the eye might actually be understood as building materials.

Site is often considered as a place of complexity which is itself a process. Architecture is an action within that process—one of many actions on the site.

Precision measured drawing is often valued over mechanical drawing and relationships between Euclidean geometries are understood as only one set of relationships between shapes. A recent preoccupation involves a discussion of drawing as it relates to new tools and new investigations of perception. The complexity of the hand and mind commands a number of both haptic and optic perceptual tools. The right tool fits the right project. The tactility of clay and its behavior in relation to gravity might be considered in one case, the capacity of the computer to generate repetitions might provide the correct tool in another.

Typically, students are no longer limited to the study of canonical buildings from classical antiquity or 20th century modernism. The search for precedent ranges more broadly and examples are more equally weighted. Now that the prescribed methods of study have been partially dismantled, the pursuit of precedent must be even more ambitious and rigorous. Computers should be an important tool in this regard. The increased capacity for storage and access might facilitate a broader synthesis of information and sponsor a more creative interplay between examples of precedent.

The individual and collective dialogue between student and studio critic is the locus of many different kinds of growth. It develops an understanding of criticism within the context of creativity, and an understanding of another student's process. In the best studios, the "desk crit" is not just a coaching session for the individual artist but an introduction to partnership, typically one of the richest and most efficient ways of accomplishing architecture. In the end, this kind of dialogue with instructors or colleagues involves rethinking the purpose of architecture and inventing new programs for buildings, constructions and landscapes.

A typical introductory architecture studio is conducted with 8-12 contact hours per week and 24-hour access to the studio.

III. Comparative Evaluation of the Architecture Program

As previously stated, Dalton's inclusion of architectural studies in a secondary school curriculum is, at the outset, exemplary and rare. This evaluation compares a secondary school program with the highest standards of university-level studios. The question remains concerning how the architecture course might be developed: is it a discipline which involves its own broad exploration and renders its own artistic growth, or is it more specifically defined as an introduction to existing architectural notions and 3-D computer modeling? Since this is the first year of the architecture program's new incarnation with computers, perhaps this is an appropriate time to ask that fundamental question. A point-for-point comparison with the changing trends in architectural pedagogy just outlined may inform consideration of this issue.

A. Subjective Exploration

The curriculum for both the beginning and the advanced architecture class begins with some subjective exploration to access the student's own spatial sense. In the beginning class, drawing seems to be the chief method of contact, and clear distinctions are made between drawing types with a very intelligent discussion of the meaning of these representational forms. Conventional architectural drawing is introduced in this context. In the advanced class, there are abstract exercises concerning linearity, rhythm, repetition, etc., which set up formal compositions to explore. The exercises reach into other disciplines by beginning with outside readings as inspiration for architecture. The best of these choices for outside reading looked at a text of science fiction or nonfiction which presented a complex new order to challenge a more conventional spatial order. After accessing this material with one tool, both classes later represent it through computer drawing.

Recommendation: The computer itself might be the tool used to access these earliest spatial explorations utilizing those program functions which are least prescriptive and allow for the most liberated exploration of more complex geometries. Three-dimensional drawing tools (including both drafting board and computer) often rely on Cartesian space and Platonic geometries. *Form-Z* operates in this way, but it also has many other tools, not only for deforming geometry, but also for generating other kinds of contours.

There might also be exercises designed around a direct translation of some initial subjective spatial object by, for instance, scanning in objects to be manipulated within the computer. Trained as a sculptor, Mr. Meredith is quite interested in diversifying media used in the program as well as discovering ways that the computer can itself inspire, just as stone or clay might be used to generate certain kinds of form and perception.

B. Conventional Drawing Skills

While conventional architectural drawing can be restrictive, the Dalton students' contact with it in the context of computer drawing seems very liberating. Students often commented on the powers of the tool in terms of being able to "see all sides" of the construction, turning or slicing or looking behind it. Certainly, modeling gives the student a similar power, however, when listening to the students one is aware that 2-D representation will never be the same for them as they watch the lines freed from the page, animating the conventional orthogonal projections. The typical first year struggle to make clear that the 2-D drawing is not an end in itself ceases to be a problem in the context of the computer. Measurement and scale, introduced in this context also become flexible tools rather than stumbling blocks.

It is perhaps worth noting at this point that, in general, students seem to have taken the inclusion of computers completely in stride. After some initial skepticism, they embraced the ease and efficiency of *form-Z* as a drawing program.

C. Structural Modeling

Perhaps one of the most impressive exercises in both the beginning and advanced classes involved structural modeling. Students are allowed to see the constructions as engaged with the moving force of gravity. Modular constructions designed in the beginning year are stacked against gravity. The advanced students embark on a much more difficult bridge project involving an actual weighted structure which must be resisted by constructions of wood.

This kind of essential architectural/spatial exercise would at first seem to require a gravity environment rather than *Cyberspace*. However, some students in the advanced class designed a cord of their truss on the computer and then replicated it in model. For some students this may be a more efficient method of experimentation. Another student in the advanced class, Jefferson Han, working on his own program, developed a way to "drop" structures within the *Cyberspace* and examine changing stresses as they registered in color.

Recommendation: The work of Jefferson suggests a number of possibilities. The rather tedious structural computations involved in, for instance, truss design might be graphically illustrated by elementary structural computer programs which quickly display, not the rules of computation, but rather the more important relationships between the size and arrangement of the pieces in tension and compression. Students can spend an entire semester building one prototype to test for structural stability and in the end they have only tested one prototype instead of testing the behavior of a number of models and understanding a number of structural relationships The accession of archival information would be useful in this regard. Certain kinds of structural relationships and details might be called up for reference. If available in abundance, these might only encourage discovery.

D. Formal Composition

I had a number of conversations with students about formal composition and geometry. This discussion is related to the above issues, but warrants separate treatment. I was concerned when looking at some of the students' work that it was generated from the building blocks of Euclidean geometry and along Cartesian principles of composition. As stated above, *form-Z* uses these geometries as basic tools. Even at the crest of the learning curve, students are rather obedient to the methods of the program, especially if they composed first on the computer rather than in model. Those students (e.g., Jeff Dvi-Vardhana) who worked first in model translated a more complex model composition of indeterminate geometry into orthogonal projections using the computer. Others were largely clinging to the X,Y, Z axis as a kind of invisible organizing principle. Many of the compositions were self-reinforcing and primary.

Recommendation: 1) The computer should perhaps not be the sole modeling tool, but should be supplemented by scale models. 2) Compositions are complicated by inhabitation and by the warp of perception. It is critical in my opinion that students understand that their compositions are not perceived or experienced as they understand them through orthogonal projections. In fact, ideally, there should be a dialogue during the earliest stages of conception in which the student "composes" in experience. The computer is an ideal tool for beginning that exploration, as the following section "E" attempts to demonstrate. 3) Specialized exercises on the computer may help to subvert the dominance of the X, Y, Z axis. [See recommendation under sections "A" and "E".]

E. Perceptual Drawing

In a typical design studio, the main tool of perceptual exploration is perspective drawing. This kind of drawing can be difficult, tedious and so time-consuming that students avoid it or never master it. It can also reinforce the illusion of Cartesian spatial perception unless it is actively redefined. For instance, changing the rules of perspective drawing or serializing the perspective in a cinematic way are both tactics which reach for a different kind of perceptual drawing. With the computer, this kind of investigation can begin almost automatically. Information can be immediately translated into a form that simulates inhabitation. The point of view can be changed at will. The student can move through the construction and even animate a computer film sequence. What would have taken hours, takes seconds, literally. This capacity for perspective drawing is perhaps the single most powerful tool of the computer program as it is being used in the New Lab. Jefferson utilized this capacity of the computer to make an impressive ten-minute moving sequence or animated "walk-through" of his bus stop project. However, he did not use the computer to compose the design.

Mr. Meredith feels that this capacity of the program is currently underexploited. I agree. Perceptual drawing is now a separate function, something sampled after the composition is completed rather than a tool engaged in designing the construction. For instance, advanced students working on a table, a chair and its housing were aware of the designs as objects but had not explored their relation to their surroundings when changing the eye by sitting, standing, and walking.

Recommendation: Mr. Meredith has proposed new additions to the curriculum which directly address perceptual drawing skills. With enough research and preparation time, he hopes to develop the animated walk-through as a fundamental component of early architectural training. Greater familiarity with the program in the coming years will no doubt allow this tool to change the way architects conceive of a design in addition to changing the way they execute its representation.

F. Light

The discovery of light as a moving building material is typically made through experimentation with models and additionally explored with perceptual drawing. In *form-Z*, point light sources can be set up and made to "shine" into the construction. They behave more like artificial light sources than natural sunlight. Just as with perspective drawing, the tool must be critiqued for its own illusions or misrepresentations of experience. For example, in *Cyberspace*, the world is either an opaque white or all black as if a representation of deep space or nighttime, a world vastly different from that of diffused sunlight.

Stratavision is a program that the architecture course is using to render the materiality of constructions. This program too is limited in its rendering ability. Objects are slick, smooth and artificially lit. There is a kind of romance with the slick "techy" object which, in my opinion, it is important to avoid. However, all of the students are aware of this limitation and that the sunlit world outside is very different from *Cyberspace*. In several conversations we compared the diffuse and bouncing light coming through the frame of the window with the crisp deep black atmosphere or the perfectly smooth synthetic "granite" rendered surfaces within the frame of the computer screen. Students immediately acknowledged this comparison with a familiar disclaimer about the representational capacities of the computer.

It is also worth noting that each of these programs does at least one thing very well. This particular program renders reflective surfaces well and shows, for instance, the changing conditions of transparency and opacity that are achieved with glass in different conditions of lighting. This kind of rendering is a particularly difficult and time-consuming process when attempted by hand.

Recommendation: *Cyberspace* remains unsatisfactory in capturing natural light. Photographs provide one of the only manageable 2-D representations since they are chemically changed by and seem to contain bouncing, diffuse light. Some kinds of drawings, three-dimensional modeling and various composites of modeling and photography also begin to simulate natural light.

G. Site

All architectural issues are, of course, related to site. Some pedagogical approaches privilege site as the chief generator of architectural form and program. It is seen as ground upon which to exercise perceptions, to bring forward a number of existing formal and cultural

> ...it seems that the true potential of the program is to understand the computer as one in a diversified set of tools, and a tool which need not merely serve received ideas about architecture but also generate new ideas, forms, and spatial conceptions. The *form-Z* program should be further explored as a tool to access creativity, and go beyond the prescribed geometries and Cartesian functions that are really just fundamental building blocks. Also, the capacity of the computer beyond the realm of drawing and modeling, its capacity for storage and accession of supplementary information concerning precedent, structure and site should be exploited and incorporated into a pedagogical technique.

forces to be transformed or critiqued by the new construction. In past years, Mr. Meredith's classes have dealt strongly with site, working for instance on a long linear site along Manhattan's waterfront. During this first year of computer use, site work has been slightly curtailed. Most of the constructions have been worked on in *Cyberspace* rather than a real site. The balance should and can be,restored.

I found the work in the senior project by Abby Rowe to be most impressive with regard to site work and to conceptions of landscape and ecology. She was working on a zoo for Australian animals in Arizona. The first formal move, making the overall site into the shape of Australia, while at first seeming a bit naive, gave her a kind of indeterminate shape of property and allowed her to focus on the contours of the topography. Ordinarily, to understand the shape of the land is quite difficult for a beginning student gazing at topography lines on a flat map. After scanning in the map, Abby was able to immediately generate a 3D contour projection of the landscape. The shape and interiority of the landscape was, of course, itself an architecture.

With no prompting, she spoke eloquently the very words that I try to elicit from my graduate students. She talked about her desire not to add more buildings to an artificial environment and, while she made plans for the use and inhabitation of the land, she built almost nothing. In fact the gazebo, the object building that was her only construction, was rather a disappointment. She might have conceived of building as landscape rather than object. Here was a case where the new capacity of the computer made it not just a drawing tool, but also a conceptual tool. Abby was in a sense truly accepting the challenge of creating a new program for architecture and landscape as well.

H. Precedent

Since the architecture program is still in its infancy, students this year were still looking at slide lectures of precedent and existing three dimensional models. While they knew much more about architectural precedent than the entering college freshman I generally encounter, I felt that they should be exposed to more historical precedent. They seemed to have a few models in their mind which perhaps loom too large. For example, classical orientations such as symmetry and axiality were familiar, and figural arrangements in plan and elevation appeared (e.g., rectangles, octagons, archways). Louis Kahn was familiar, and some of the use of primary geometries was reminiscent of his work. When I drew diagrams of, for instance, a Miesian notion of spatial continuum, they quickly grasped the difference between it and classical spatial orientations. However, since they could not volunteer the information independently, I did not feel that most of these students possessed knowledge of a very broad set of alternative precedents.

Recommendation for Site Work and Precedent: An architecture student's understanding of site and precedent should be enhanced by computer technology.

Information about sites in the form of maps, plans, aerial photos and photographs might also be a resource. In the not-too-distant future, it should be possible for students to access enormous amounts of material within a shared network or from CD-ROM discs. Mr. Meredith has proposed to make just such a slide collection. Many more collections will undoubtedly be formulated in the very near future.

I. Teacher/Student Dialogue and Inventing New Programs for Architecture

Architecture is a discipline which relies heavily on partnership and collaboration, and a kind of creativity which is constantly relinquishing authorship at various stages of the work. This process is itself a kind of training which renders its own intelligence to the student and which seems to be a major part of some of the New Lab programs. Dialogue with teacher and student is one place where a new conception of program can be forged.

I found most of the students to be quite impressive in conversation. As I have mentioned, Abby's discussion of landscape was distinguished as that of a truly independent thinker. Jefferson was very responsive in conversation, quickly moving between the abstract and the specific and confident in his ability to solve problems. Jeff Dvi-Vardhana was focused, cooperative and seemingly very aware of how to value and follow his creative impulses. In general, they were so mature and intelligent that I had to continually remind myself that they were high school students.

But some of the advanced students were not always attentive to the program suggestions provided by Mr. Meredith. The design was meant to incorporate a book that the student had read, but upon questioning, some students didn't seem to be making connections between the cultural contribution of literature and architectural design.

Abby and fellow senior George Soo were working on final projects where they had devised their own program, chosen their own site and were proceeding with a design that included a full range of drawing types. The format of the senior project and the use of computers to accomplish the project clearly made the discipline of architecture into another kind of activity for these students who had not previously been very keenly engaged in studio. In both cases, landscape became something which could finally be represented, modeled and considered as a major part of the design.

Jefferson is not only able to program the computer himself and devise what would be the equivalent of quite advanced methods of imaging, but he also has a very complex intellectual sense of the computer's cultural significance. He may romanticize the "techy" aspects of the computer visuals, but only with a sense of irony.

While I was slightly disappointed that he had not completely grappled with ideas of interiority, he had produced a animated walk through of his bus stop project. Jefferson can see the computer world within a larger relational intelligence that truly gives him a different epistemological ordering device. It is almost impossible to think of him in a high school situation where computers are not available.

Recommendation: 1) The studio might experiment with more formalized "desk crits" in addition to the trouble-shooting, consultation and teaching which Mr. Meredith provides. In other words, students would have to be prepared for a classroom interview. 2) Classroom process does not yet fully exploit the network capabilities of the computer, either in accessing precedent and site information or in strengthening a collaboration between students. Eventually, accessing large databases of information should also enrich the dialogue between teacher and student as well. A typical "desk crit" could be the specifically tailored lecture that teachers dream of being able to provide.

4. Summary and Conclusions

Most of the recommendations have been interspersed within the previous pages. However, to recap, it seems that the true potential of the program is to understand the computer as one in a diversified set of tools, and a tool which need not merely serve received ideas about architecture but also generate new ideas, forms, and spatial conceptions. The *form-Z* program should be further explored as a tool to access creativity, and go beyond the prescribed geometries and Cartesian functions that are really just fundamental building blocks. Also, the capacity of the computer beyond the realm of drawing and modeling, its capacity for storage and accession of supplementary information concerning precedent, structure and site should be exploited and incorporated into a pedagogical technique. Since the profession often involves collaborative work in teams or partners, the networking capacity of the computer could begin to exercise these skills. As with any tool, the students must understand the limits of the computer to represent experience and the atmospheric conditions which are very different from the representations of *Cyberspace*. One currently underexploited capacity of the computer is in simulating movement and interiority within the structure or from the point of view of perceptions.

On a practical note, it seems as if the New Lab is a bit understaffed in terms of computer maintenance and students have too often had to postpone work while waiting for system problems to be ironed out.

In closing, I return to the fundamental question about specific goals for the architecture program within the New Lab. Is architecture to be used like archeology, as a discipline which engages a broader cultural history and creative inquiry? Or is the studio more like a 3-D modeling class which could be preparation for a number of different endeavors on different scales within different disciplines? Is the computer a tool more immediately linked to an accession of a new consciousness about spatial perception? Finally, since these are challenging questions even on a university level, to what degree can they be engaged in secondary school?

Note: I find some of the ideology about the Post Modern School and the references to technological "advances" to be bound up in positivistic ideas of progress. I find these ideas sometimes create an environment as deterministic as the most *de rigueur* of traditional settings. If the technologies allow us to access more information and in a nonhierarchical way and chart a number of different courses through a body of information, might they not further inspire us to diversify our tools? I ask this question because it seems to me to be fundamental in evaluating the architecture program and the use of new technologies within the stated goals of the New Lab.

* * *

Evaluation of *Project Galileo:* Michael R. Rampino, Associate Professor and Chair, Department of Applied Science, New York University, New York, NY

Introduction

Professor Rampino has worked for many years with colleagues at Columbia and New York Universities searching for ways to make real science accessible to all students. One can get a good sense of the unique way that educational concepts govern the use of the computer under the Dalton Technology Plan simply by juxtaposing Professor Rampino's evaluations of *Ecotype* and *Project Galileo.*

The last few years have seen a great increase in discussions of educational reform in the teaching of science at all levels, and of the possibilities of utilizing computers to make the classroom an interactive, "hands-on", learning environment. Science literacy has become an educational buzz word, but unfortunately there has been little agreement as to what science literacy for the nonscientist really means. The old argument of depth versus breadth in science education is again a center of disagreement. More traditional educators believe in a back-to-basics approach, with a thorough grounding in the principles of physics, chemistry, and biology for nonscientists. Others believe that science literacy should involve the ability to understand current science at the level of articles in the *Science Times* , and hence what is needed are survey courses in which students learn a little of what is important from each of the various scientific disciplines.

Some science educators opt for courses that stress the "scientific method"—how science is done—and assign the reading of classic scientific research papers to students with the idea of presenting a narrative of the scientific process. The students read about how scientific research was done (from formal papers that do all they can to hide the often intuitive nature of scientific discovery), and this is supposed to excite them to the theory and practice of science. One text even speaks of the reading of technical papers as a "hands-on substitute" for actual demonstration and laboratory work.

At the same time, the presence of computers in the classroom can no longer be ignored, and thus in most of this talk of reform in science education, attention is given to utilizing computers by the instructor for demonstration purposes, and in science lab classes.

It is easy to see that these proposed reforms really involve mostly "old wine in new bottles" (or often "old wine in old bottles") without any real change from the traditional ways of teaching science to the nonscientist or the beginning science student. The underlying belief in all of this seems to be that science can be *done* only by a few especially committed or talented students, and only at an advanced stage in their education. All others are bystanders who must simply read or be told about scientific discoveries. Thus, science for the nonscience or beginning science student must always involve a one-way flow of information from the knowledgeable instructor and the textbook to the student, with little chance of the students actually discovering something on their own. Lab exercises are often little more than cookbook recipes, and computers are just hi-tech trimming on the traditional methodology of science education.

Are these the limits of innovative science education, or are there other possibilities?

I used to be a big performer...give lectures and entertain my students while instilling science, it's kind of a whimsical rigor that I used up in front of the class, an act so to speak. And I was really concerned that I would miss that. But as it turns out, I don't miss it at all. Because I am literally all day long interacting individually with students. And it's a much more enjoyable, a much more personal kind of thing...Students don't see astronomy as a kind of lockstep class, homework, test situation. They really view it as a work week. Typically their work exceeds their scheduled class time by a factor of two.—Malcolm Thompson, Apple's *Imagine* series.

The traditional ideas of science teaching and learning are now being challenged at Dalton in a number of classes including *Project Galileo* (Astronomy 301), a college-level Astronomy course, offered to secondary school students, that has been running for the past two years. The philosophy behind the course is simple—students learn better by doing—but the course has an innovative structure based on a carefully designed series of tasks that the students must complete on their own and in small groups, and it is heavily dependent on the use of the new technology. Computers, however, are not utilized merely to teach facts about astronomy to the students, or to demonstrate, through simulations, scientific laws or processes; they are used as a tool to provide direct access to the kinds of observations, data, and techniques used every day by working astronomers.

The availability of these data and the manipulative power of the computer mean that the students in the course can act in the same ways that "real" scientists act. They are presented with a series of research projects or "tasks" that at first may seem impossible based on each student's knowledge and background. But with the help of information that the students search out for themselves with the help of the computer, the guidance of the instructor, available print resources, and the cooperative effort that comes from working in small groups, each student finds his or her way to work through the assigned tasks.

More importantly, however, they come to the realization that the completion of the tasks leads to other larger questions and insights, in the same way that working scientists find that the "solution" of one problem leads to important insights and further questions, far beyond what was contained in the original task. In the Dalton Astronomy class, from what I have observed, students are, in a very real sense, *doing* science, and this seems to represent a very viable alternative to traditional methods of science teaching that have contributed to the current crisis is science literacy.

The visit to Dalton

I spent several days at Dalton School (May 10, PM, May 12, AM, and May 13, 1993 AM) meeting with the instructor and students of Astronomy 301, and observing the classroom activities. During that time I spoke at length with the instructor of the Astronomy 301 course, Malcolm Thompson, regarding the philosophy behind the course, the course design and history, problems that had to be overcome in designing the course, and plans for changes and improvements in the course in the future.

The course is a college-level, full-year "modern astronomy for humanities students" course based on extensive use of computer technology, and Mr. Thompson demonstrated the use of the various items of computer hardware and software utilized in the class by the students. I looked over the various print resources (texts, sky catalogs, etc.) available to the students, and the instructor also provided me with copies of all the previous tasks given out in the course.

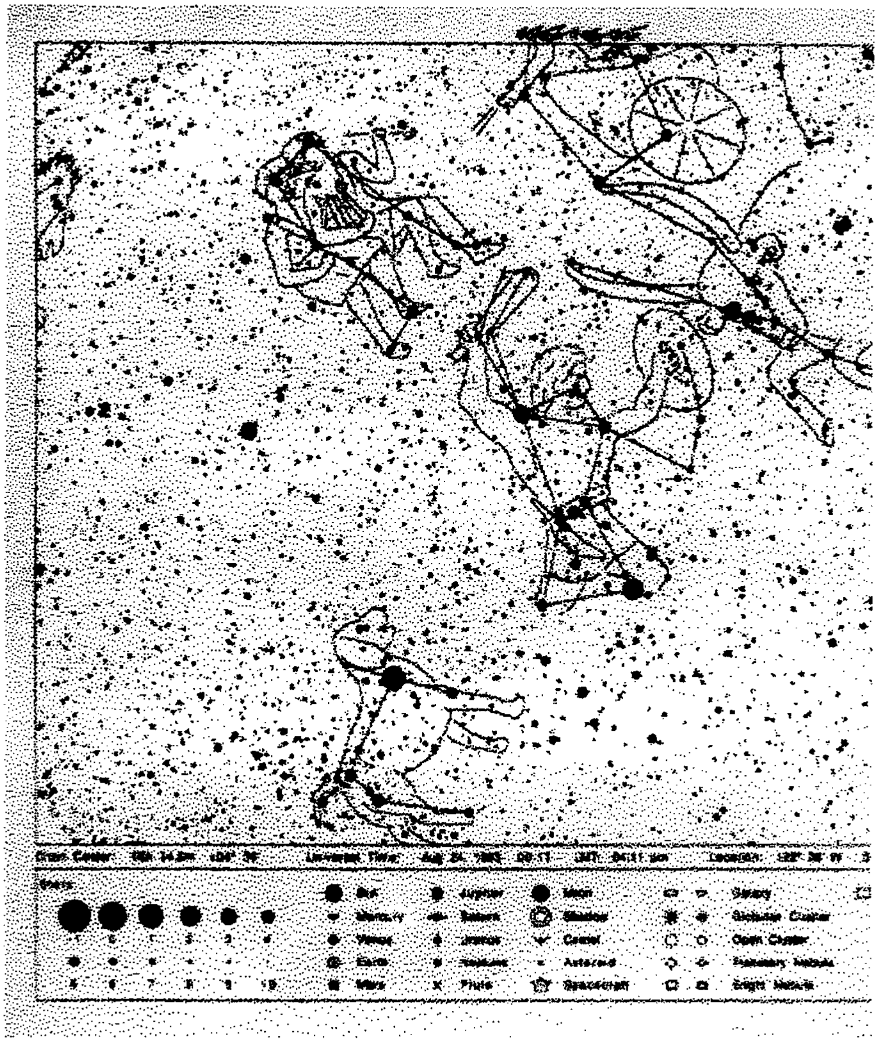
I spent several class sessions with the Astronomy students (most were high school juniors and seniors). During the class time, I looked over the students' shoulders as they worked around the computers, and asked questions about what they were doing and why. I observed the way in which they worked together in small groups, and I tried to test their comprehension of the subject matter of the exercises by asking pertinent questions, but often just listened in on discussions among the small working groups of students. I tried to determine each student's background in science and mathematics, and their previous experience, if any, with computers. Although most of the students had taken high school physics, chemistry and biology, many had typical math anxiety and little real experience with computers beyond word processing. I also had the opportunity to speak candidly about the course with individual students or with small groups in the classes.

I asked for demonstrations of the students' abilities in using the various computer programs utilized in the class, and observed their degree of comfort with the computers in general. I later examined many of the written reports that students had submitted for earlier tasks completed in the course, the examinations used to evaluate students, and written student evaluations of the course. My observations on what I think are the most important aspects of the course follow.

Use of classroom time and space

The Astronomy Lab opens at ~7:30 AM, and is available continuously until ~6:00 PM (I think that sometimes it is open even later). Students can also come in on weekends, and many do. Although the course is scheduled to meet weekly in three 45-minute classes and one double (90-minute) laboratory session, the problem-solving structure of the course largely obviates the formal schedule, creating a more-or-less continuous work week. Students spend a lot of time in the Astronomy Lab, and most students admitted that regular classroom time was never enough to complete the tasks.

During the time that the Lab is open, the students in varying numbers are present working with each other in small groups, and interacting with the instructor. The explicit goal is to complete the designated tasks, which usually are assigned one per week. Mr. Thompson is always in residence, and the presence of the instructor as a resource is an integral part of the discovery process that goes on in the Lab.



Star Chart from the Voyager II Program

Sky Sector as it appeared in San Francisco, California

4:11 pm on August 24, 1993

Classroom time was fully utilized (students seemed reluctant to leave), and students who did not finish their assignments could come back any time that the room was open to continue their work. Many students told me that they spent more time on the Astronomy course than any other in their Dalton career, but most said that they enjoyed every minute of it.

Although the Astro Lab (students call it the Astro-Cave) is rather cramped, it is cozy and actually may be well-suited for students working in small groups. It provides a rich learning environment consisting not only of the networked computers, but also of scanners, sky catalogs, all the recent astronomy texts, other books and scientific papers, and pertinent charts and diagrams. It wasn't designed specifically for the use of computers, and thus the setup can be a little awkward. For any increase in class size, a larger space is obviously needed.

Interaction among student groups and with the instructor

The work requires intensive and continual interaction among the students and with the teacher. A typical day involves work on the computers or with other materials, interwoven with a series of ongoing discussions within the small student groups (3 or 4 students each), and with the instructor who is always there to ask and answer questions. The students were never passive, but were normally actively engaged in trying to figure out the best way of completing the assigned task. Rarely, a student did not work well with the other members of his or her group, or goofed off while the rest of the group was working, but this seems to be a special problem of a few students. Most seem to be interested, active, and self-motivated. The instructor showed that he knows who does the work and who slacks off, and grades are based partly on the students' attitude.

Each student is responsible for completing each task by the assigned date, sometimes individually and sometimes as part of a group. The group activity is an integral part of Astronomy 301, but does it contribute in a positive way to the learning environment? My observations of the class show that there is a constant exchange of ideas, recommendations, and criticism among the students, and with the instructor. This is apparently an integral and important part of the learning process. As one student put it, "Mr. Thompson and the other students form a support system, and if the student has any questions, both are readily available."

Most groups seemed to have an individual who took a leadership role (I am glad to see that this was as often a female student as a male), but the give-and-take associated with the group effort seemed to force all of the students to interact, collaborate, and compromise with others, very much as researchers must do in the real world of science. This is very different from the conventional format of science classes where students usually cannot work together on problems, and where the situation always involves competition for grades. Through the group process in Astronomy 301, students are forced to improve their interpersonal skills, while at the same time, the lack of traditional class structure seems to act to increase their self-reliance (see below).

Classroom atmosphere and student engagement

The rapport between the instructor and the students could hardly be better. The students treat the instructor as a valued friend, and seem honestly happy to be in the class. In many ways the instructor in Astronomy 301 is more like a research advisor or mentor than a teacher. He is often asking questions, or more likely "answering a question with a question" in order to stimulate the students' curiosity, or leading them in an interesting direction without really seeming to be leading them that way. The instructor is extremely patient with the students, but it is more than that—he honestly seems to enjoy every interaction with the students. No question is too trivial to command his attention, and he seems to understand that sometimes the most trivial question may lead to a new insight. Some of the students told me that this was the class in which they felt most comfortable, and time spent in the Astro Lab provided a welcome respite in a long day of competitive classes at Dalton.

Students at work on Project Galileo

The atmosphere in the classroom conveyed the kind of enjoyment in the creative process that good science should always be. The class is very informal, and there is little of the kind of pressures that one finds in other classes. I was therefore a little surprised at the level of student engagement in the course. The room was always buzzing with activity as the students worked in groups, and the instructor's voice could always be heard above the buzz, asking and answering questions, cajoling the students, and providing guidance wherever needed.

Efficient work habits are important in order to complete the assigned tasks, and the students showed that they have learned how to address a problem and rationally search for the answer. They showed a remarkable degree of confidence that they could master any new concept in astronomy. After all, they have successfully mastered all the concepts thus far. I found this very different from the uncertainty and doubt that permeates standard lecture classes.

The organization of the course seems to force students to work and think harder than they would in a normal lecture/lab science course. Working together to complete the assigned tasks apparently gives the students a sense of involvement and satisfaction at completion that they would never get in a traditional class. As one student said, "In Astronomy, hard work always pays off."

Group work and individual work are both important in the Astronomy 301 classroom. Students must be able to accomplish individual tasks that they take on as part of the group, and, of course, work on examinations on their own, while at the same time acting as part of a larger group in completing entire assignments. One student said that the course helped him to realize his own capacity to fully commit himself to his work (both individually and as part of a group), because the course demands that he do so. Self-motivation is the key, as it always is in the real world of scientific research, but the group structure also allows the students to strengthen their skills as team workers.

Clearly, the amount of information acquired in Astronomy 301 depends upon the amount of effort that the student puts into the class. Attitude and motivation are important, and the problem solving nature of the course seems to foster a positive attitude and self-motivation. It is noteworthy that part of the grading is based on the students' attitude.

The only complaints I heard from students were that some students don't carry their weight in the class, and take advantage of the free atmosphere to hand in assignments late. But these students apparently represent a small minority of those taking the course.

Teacher commitment

One of the strongest points of *Project Galileo* is Malcolm Thompson, the instructor and designer of the course. From my conversations with Mr. Thompson, it is clear that this astronomy course comes out of his personal mission to develop new ways of teaching and learning science. The commitment has gone from wrestling with his personal dissatisfaction with most current methods of teaching, and examination of the philosophical bases for science teaching, to designing and carrying through the responsibilities of teaching a new kind of science course at Dalton.

> Their progress in the tasks leads them to an understanding of the scientific method that no textbook description could give. The *students* make the observations, *they* generalize, making rules that seem to fit the data, and finally, *they* apply those rules to new situations in order to test their hypotheses. Thus, they learn, by doing, how to generalize their experience into a synthesis.

Mr. Thompson is clearly very knowledgeable about astronomy and about science in general. He is co-author (with Robert Jastrow) of one of the most popular astronomy texts for college students. When I observed the class, he was able not only to answer any questions about the course material, and help with computer problems, but he also had the knack of asking the right sorts of questions of his students to prime them for future discoveries.

Mr. Thompson is constantly tuned in to what is going on in the classroom, which seems incredible since there are usually several things going on at the same time among the various groups at work in the class. In one laboratory exercise that I observed, for example, a student was about to ask a question and Mr. Thompson said, "45°" before the student could get a word out. Commonly, Mr. Thompson will answer a question with another question, which often can be more helpful than an answer. He is thus very skilled at guiding students to their own discoveries.

This all looks like very hard work, but Mr. Thompson told me that he finishes a long day at Dalton feeling refreshed (I only partly believe this after seeing him work so hard), as opposed to the fatigue he felt in past years after giving standard lecture/lab courses. He said that the change is due to the fact that he no longer has to put on "performances" for students in lecture classes. His much more natural role as an advisor and facilitator of independent research is much more rewarding and much less artificial, and apparently more relaxing for him.

Subject matter—Comprehension and retention

What do the students do in Astronomy 301? The students are clear on this, they do astronomy. Real astronomy. Through extensive use of resources such as computer programs, images, data, various sky catalogs, diagrams, charts, etc., the students learn how to make their own discoveries about the nature of stars, star clusters, galaxies, the structure and nature of our own galaxy, and the evolution of the universe. The availability of the computer, and the actual astronomical data, take the student out of the confines of the classroom into the real scientific world.

The instructor usually introduces an idea in class, and then presents the students with a task that serves to strengthen the idea, usually by allowing the students to discover something new for themselves. At the beginning of each section of tasks the students read and are sometimes given lectures on some of the essential information for the upcoming tasks. But this is merely preparation for the real work. The course incorporates many resources, and in most situations it is up to the student to determine which resources will be necessary for a specific task. The tasks usually involve some type of observations and calculations using authentic scientific materials including the *Voyager* desktop planetarium program, actual Palomar Sky Survey Plates that are scanned into the computer using the Image 1.26 program and manipulated in various ways, or the results of direct observations of the sky. The observations are often designed to confirm what was discussed at the beginning of each section. Often the students set out to find the answers to questions left open in the early stages of each assignment.

In this situation, the students first enter into an incomprehensible landscape, and they have no idea what questions to ask. Before long, however, using the resources of the computer, the instructor, and other members of their group, they begin to see how to navigate in an unfamiliar situation. In fact, Mr. Thompson was amazed at how soon the students began to talk in terms of numbers, and in doing so entered the formal system of science. The students soon begin to see how powerful this system of knowledge is. Although the projects looked incredibly intimidating at first, by the time they are completed the students have mastered the material.

The value of the "task" approach seems to be that the class is given a goal, i.e., a level of knowledge which should be mastered after a given time. For example, the students are required to calculate the various characteristics of the planets, and out of this comes a realization of the different types of planets and their very different origins. Or a study of the characteristics of stars using the Palomar Plates results in the students "discovering" the H-R diagram and investigating its implications.

Their progress in the tasks leads them to an understanding of the scientific method that no textbook description could give. The *students* make the observations, *they* generalize, making rules that seem to fit the data, and finally, *they* apply those rules to new situations in order to test their hypotheses. Thus, they learn, by doing, how to generalize their experience into a synthesis. Whereas, other science classes restrict the learning to one pathway, in Astronomy 301 the students learn through the individual pathways taken while completing the projects.

One valuable aspect of the course is that it continually builds on material already learned, and thus demands comprehension, rather than memorization, of the subject matter. The information that the students get is the direct result of their own efforts and observations. The students are experiencing what they are learning. In Astronomy 301 the students are in the lab all of the time, but it is not a lab of cookbook exercises, it is a lab where the students complete tasks in order to make their own scientific discoveries. The students learn to think like a scientist—they must in order to solve the problems associated with each task. As one student said, "Understanding the course material is, in fact, almost inescapable as a result of this approach." From time to time, there are graded evaluation exercises in which the students must make interpretations of the properties, relationships, origin, and evolution of astronomical objects given only some spread sheet data, or, in some cases, just the location of the objects in the night sky. These exercises require submittal of "word-processed documents graded for completeness, resourcefulness, lucidity of supporting documents, logic and clarity of explanations" of how the students came to their interpretations.

The students were all of the opinion that there is no busywork in Astronomy 301—every bit of work is essential in order to complete the assignment and to come to an understanding of the material. The quality of knowledge attained seems to be considered much greater by the students themselves than most science classes simply because it becomes real for the students. Most students admitted that this was the hardest course that they were taking but also that it was their favorite. They also generally felt that their retention of the subject matter of Astronomy would be much better than retention in "normal" science classes.

One of the most surprising things that I encountered was the students' way of thinking about the astronomical relationships that they studied. When I attempted to test their retention by asking questions about some of the topics that they had encountered in tasks

> *We have 100 Palomar plates here with maybe 5,000 galaxies on them. So if a student wants to investigate a galaxy, he or she can make the scans of the red and blue plates and measure the temperatures, apparent magnitudes of these things. So it's a much more active process than pictures in a book. In fact, the first thing the students do now when they see an interesting picture in the book is scan it in to get into this image software in order to fiddle around with it.*—Malcolm Thompson, Apple's *Imagine* series.

earlier in the year, something very interesting was revealed. Instead of merely searching their memory for the answer, they expressed their thoughts in much the same way as I would—they figured out the answer based on relationships that they had learned or discovered during the course, e.g., I know the relationship between a and b, and I know the relationship between b and c, and thus the relationship between a and c must be this. This type of thinking is very rare in most introductory astronomy classes!

The students generally agreed that the course is hard work, involving long hours in the Astro Lab, but they also agreed that the work is rewarding and the time is well spent. They are generally interested in taking more astronomy later, in college, but realize that the courses will probably not be like Astronomy 301 at Dalton.

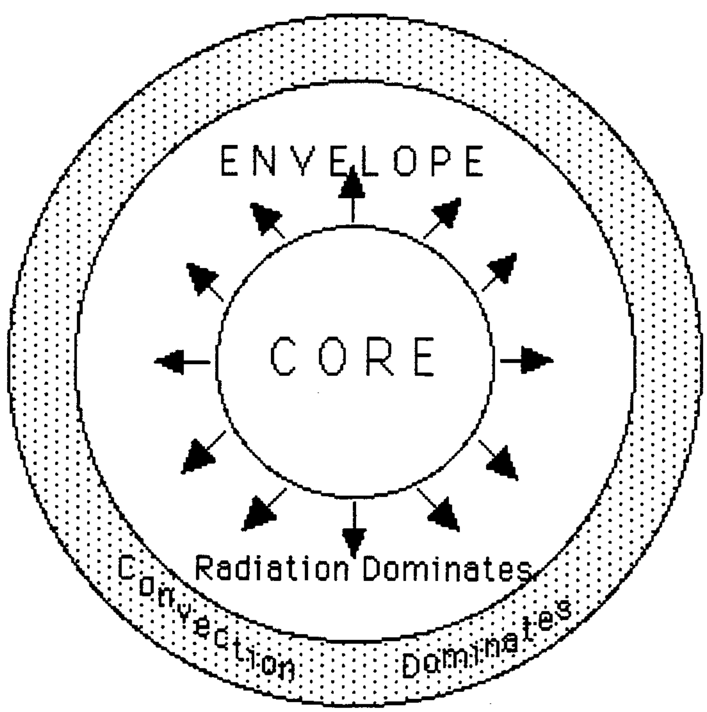
Use of computers in the course

For *Project Galileo*, networked computers throughout the school (the present Dalton network links about 120 machines) give the students access to the information that they will need to accomplish their research. The resources include *Voyager*™ (a powerful desktop planetarium), digitized versions of the Palomar Sky Survey Plates and other images, and computerized data bases of various kinds. The planetarium program allows the students to become adept at using the standard cataloguing and reference systems for managing astronomical objects. They essentially have the celestial sphere, past, present and future at their fingertips, and they can thus concentrate on the conceptual problems, leaving the labor of calculation to the computers, as it should be.

My interviews with the students show that by-and-large they have had little contact with computers prior to the Astronomy course. One student admitted that "it was the first time I've ever used a computer for the process of learning in a class." However, by the end of the year they could demonstrate to me that they have become adept at manipulating all aspects of the planetarium program, spreadsheet programs, sophisticated image-processing programs, HyperCard for reports, and have even improved in word processing, which prior to Astronomy was the only use they had for computers. The students' use of computers seems to have greatly improved their ability to visualize relationships through graphing and mathematical analysis. Furthermore, I detected little difference in male vs. female abilities with the computers.

The centrality of the computers to the activities in Astronomy 301 is an apparently critical factor in its success. The students treat the computer as a source of information, on a par with the instructor. The computer is not seen by the students as something artificially introduced into the classroom, but as a center of information around which the students, in their small groups, are always clustered. During my observations, the computers were often being used by two or three people at once and thus became centers of activity within the group setting. A conventional astronomy course would call for little or no interaction with computers, and hence would do little to allay students' apprehension about computer use.

From modeling data for stellar interiors, the students assemble a graphic cross section of a star. The original computations were done on a large mainframe computer at a research facility and published as extensive numerical tables of temperature, density, pressure, luminosity, etc. for fifty interacting levels within the star. Such large scale computations are beyond the reach of Dalton students, but the results are interpreted by them and translated into the more easily understood schematic, scaled diagram below.



Possibilities

The possibilities for expanding on a course such as this would seem to be enormous. Although some of this is already going on at Dalton (e.g., *Ecotype*), I can see the same sort of discovery-oriented format as a way of making other complex sciences such as geophysics, ecology, etc. accessible to students with diverse backgrounds. Of course, such expansion will require instructors trained to use the computer in a problem-solving environment (see below).

Naturally, one sees great possibilities in the dissemination of *Project Galileo* type courses outside of Dalton, and eventually to schools across the nation. It will be a great challenge to attempt to transfer *Project Galileo* to schools with resources that are more constrained, and student populations that are less advantaged. This would take considerable resources and man- (and woman-) power, but I see it as a necessary step if this type of science course is to be seen as a real alternative to traditional science teaching.

Recommendations

It is difficult to make specific recommendations on how to improve this course. The course was obviously carefully planned, and from what I have seen it runs very well. Many of the "bugs" in the course were ironed out during the first year that the class was taught. Mr. Thompson has told me about certain minor problems in the course that he thinks could stand improvement, and he is apparently planning to expand the course to include material on earth science and the evolution of life. I think that this would be a valuable addition, and would make the course a true picture of cosmic evolution.

One problem seems to be how to motivate all of the students to participate fully in the discovery process in Astronomy 301. In some students, the traditional ways of learning may have become so ingrained that it is difficult to get them to open up to new learning situations and possibilities. However, I do not think that this is an insoluble problem. The discovery process of learning seems to be something that will blossom in students once they allow themselves to become fully immersed in it. Perhaps as more classes are run in this way (which I hope will happen), the students who have become more set in their ways will open up to new styles of teaching and learning.

This is clearly a very popular course among the students who have taken it at Dalton. I certainly recommend an expansion of the course, but to do this additional instructors as knowledgeable and committed to this new approach as Mr. Thompson must be recruited. In order to help do this, I recommend that candidate instructors take the course with Mr. Thompson. In this way, they will have a chance to experience the sense of discovery that the course apparently produces. Although I have taught college astronomy in traditional formats for many years, I would very much like to take the course myself.

Summary

The reason for the creation of the *Project Galileo* course at Dalton may be summarized in an observation by Malcolm Thompson that in previous standard lecture/lab format astronomy courses, "the students enjoyed hearing and learning about astronomy, but they remained external to it as a process of thought. Little opportunity was available to them to engage their intellects in the experience of doing astronomy. Without that experience, they remained unable to make original proposals in science within the constraints of physical law. They were even less able to initiate a course of inquiry once a proposal was made. While they learned some interesting facts, they retained their feeling of lack of intellectual entitlement within the context of the discipline. The activity remained passive."

The goals of *Project Galileo*, therefore, may be summarized as making astronomy 1) accessible to the student; 2) concrete; 3) immediate; and 4) exciting. My observations lead me to conclude that the Astronomy 301 (*Project Galileo*) class is a great success in each of these areas.

The success has come through the innovative use of the computer to give the students access to the kinds of data and procedures that astronomers utilize in their attempts to answer questions about theuniverse. This access, combined with the organization of the course around the completion of a number of tasks, gives the student their "intellectual entitlement" in astronomy. Now, they can ask and attempt to answer questions about the universe. Once preliminaries are out of the way, the students are allowed to plunge into the experience of doing astronomy, and from what I have seen and heard, the results are stunning.

By every measure that I can judge from observing the students: 1) development of problem-solving abilities; 2) development of good work habits; 3) motivation; 4) degree of comprehension of subject material; 5) retention of material; 6) improvement in computer skills; and 7) enjoyment, the course is a great success. Furthermore, the students have gained knowledge of the scientific method in ways they never could have just by hearing about it in a traditional astronomy course.

My overall rating of the course in terms of concept, implementation and results is excellent.

In conclusion, I quote another student who summarized the course in a sentence: "In Astronomy 301, the students actually *do* the discovering, and thus there seems to be no way for them to avoid understanding what they have done".

* * *

From Appomattox to Malcolm X: Civil War CD-ROM History and the Future of History Maker: Mike Hyatt, Wesleyan University

The 1992-1993 Civil War Project continued in the tradition of last year, by walking a "fragile" tightrope that blended primary research, historiographical point/counterpoint, and hypermedia technology. It focused again on the New York City Draft Riots of 1863 and attempted to illuminate for students how this local event served as a microcosmic glimpse into larger national political, social, economic, and military exigencies. Although based on more limited contact with the students who participated in the course during the 1992-1993 academic year, this evaluation, on the whole, reaches conclusions similar in nature to those articulated by Steve Golin in *Risk and Renewal: First Annual Report 1991-1992.*

The Students

> *I think that the kids who've been through this course since last year will know what history is in a way that only makers of it can know. And suddenly, all this stuff that they've been living with all their lives which, from the point of view of time, has been nothing but surfaces, turns into something more meaningful.*
>
> *A lot of what we're doing is revitalizing the plan that this school was originally founded on in the context of these new technologies, the hope being that in spite of the bureaucratization and in spite of the need to process and sort, the technologies have the power to provide the environment that makes that kind of student-centered inquiry possible again.*— Tom de Zengotita, Apple's *Imagine* series

From the outset it is clear that the students came to the course with high expectations. Mostly these centered on working with "cutting-edge" technology and delving into history in a way that was perceived of as "nontraditional" in juxtaposition to the Dalton norm. All students commented extensively on the historiographical analyses and discussions that comprised their early course work and expressed astonishment that historians were not value-free recorders of past events. Issues of bias, both in the selection of facts and in their interpretation, were clearly strong points of the early days of the course, although the students believed that "too much time" was spent discussing the historian's craft. Although all admitted that their first exposure to subjectivity in history was eye-opening, in retrospect they believed a shorter concentration on this aspect of the course would have allowed them more time to master the *HyperCard* technology and to work on their own research projects.

Without openly acknowledging the extent of the influence that these discussions had on them, all the students understood that historians emplot a particular type of story on a past that they create from carefully selected evidence. In other words, the students understood for the first time that history is biased, subjective, closely tied to *zeitgeist,* and therefore that it must be continuously challenged and deconstructed. Moreover, after learning this lesson, they became self-actualized historians themselves, each with a story to emplot, each needing to grapple with the same problems of bias that mark the discipline on its professional level.

Concerning the nature of the primary research which students conducted, opinions were uneven. One student, who had been in the course for two consecutive years, clearly benefited from extra time. His project was completed, polished, and demonstrated a thoughtful selection of research material, with useful analytic insight added. He commented on the pleasure he experienced in navigating his way through the material and was impressed to reflect back on the vast amounts of knowledge he had gleaned about the draft riots themselves. For him, the project was empowering and provided a taste of what the discipline of history could offer. But he was not as comfortable discussing the national aspects of the Civil War period. Although he could relate the causes of the riots to some national, political, social, and military trends, these aspects of his knowledge were clearly not as detailed nor as thoughtful as the more localized material.

Another student, who chose to concentrate on New York literary figures and their views on the Civil War, expressed frustration over the lack of time she had "to do" research and finish the project. Although she had clearly devoted valuable time to thinking about her author-of-choice, Herman Melville and his poem,*The House-Top*, she was unable to create the type of linkages in her project that she desired. In this case, she was pleased with the latitude that allowed her to do primary research but was frustrated by the time obstacle that limited her ability to be thorough and expansive.

A third student also felt stymied by the research and did not complete his project. Citing a paucity of material and limited time, he also desired less historiographical introduction and more "free" time to conduct research. Much as the others, however, he was enriched by his archival experience and only wished it could have yielded quicker and better results.

Technological mastery, the third leg of the process, received the most diverse commentary. Two students who had enrolled in the course for the first time discussed the large amount of time invested in acquiring basic skills necessary for HyperCard literacy. One believed that although a certain amount of technology was needed and was useful, she would have preferred to do more primary research, unfettered by the requirement that she become proficient at the technology. For her the research was invigorating and empowering, especially since it followed the historiographical lessons that opened the course. This critical bifurcation of energy between research and technological mastery frustrated her. She felt that she "barely touched the surface" of her work because she needed to "master the medium of HyperCard." But, when asked whether she would have preferred doing more in-depth research which culminated in a traditional written term paper, she said no. Frustration notwithstanding, she preferred the hypermedia approach, despite its perceived limitations and difficulty of mastery.

The student who participated in the course for two years was far less critical of the technological issues and had certainly learned a great deal about the process. Again, the extra time proved critical to his success and learning, as was demonstrable in assessing his project.

In sum, when assessing the degree to which students in the 1992-1993 phase of the project met the goals for student achievement, as outlined in *Risk and Renewal*, the same strengths and weaknesses come to the fore. Students learned a great deal about historiography, especially concerning subjectivity, political bias among historians, and manipulation of evidence. Clearly, they did not approach a graduate-level understanding of these issues, although that possibility is by no means beyond their reach or the course's potential. Nonetheless, at present, there is no evidence to suggest a real familiarity with Civil War historiography in general, nor any analytical insights into dominant schools of Civil War scholarship. On the other hand, all the students emerged from the course with a strong understanding of local New York issues and how these were created and shaped by the Civil War. Moreover, they gained a deep insight into the Draft Riots themselves. These strengths did not, however, translate into an equally trenchant understanding of the "Civil War in a national context." Finally, students admitted that this year, much as last, they learned basic computer skills, but that the programmer did the bulk of the complex navigating and designing.

The Projects

Careful scrutiny of the hypermedia projects created during the past two years of the Civil War course reveals much positive achievement, some student frustration, and clues for future improvement. All the efforts reveal diligent research and reflect the enthusiasm which students brought to the course. The strongest aspect of all the projects was the collection of primary materials, which as a whole represented a substantial body of evidence on the draft riots and themes tangential to them. In each case students attempted to grapple with this material in fashioning some type of historical assessment, although here the results were more uneven.

In counterdistinction to the finished quality of the above-mentioned work, the Melville project and the effort on the New York City public school curriculum were unfinished. The authors of both these works continually expressed regret that they could not do more and both hoped to complete their projects at some future date, despite the fact that they have both now graduated from Dalton. In both cases, these projects were at their best in displaying the research collected by the students. Moreover, it was evident that both students intended to expand into historical analysis and wanted to create hypermedia links. They simply ran out of time. Interviews with them revealed a determination not merely to "paste" images into the project. If the material could not be placed in a manner satisfactory to them, and assessed accordingly, they preferred to leave their work unfinished.

The projects clearly empowered these students to engage directly in the process of historical research. They experienced the frustrations that arise when material is difficult to unearth or not sufficient, and the elation when a corpus of important documents is uncovered. As was the case the previous year, all students learned a great deal about research, and armed with their new awareness of historical manipulation, they engaged in an important educative act of scholarship.

In the streets of New York City with Powerbooks

The Future

The Civil War course brought to light a number of revealing insights into Dalton students and their historical knowledge. Certainly, students enrolled in this advanced course had not had sufficient prior exposure to historiographical debate and interpretation. Moreover, they arrived at their senior year with a naive faith in historians that precluded possible biases and other motivations which help those who study the past to select and fit in their facts around their thesis. The opening weeks of the Civil War course shattered that naiveté. But such academic sophistication came at a high cost. It took time to discuss these issues surrounding the idea of history, and these class meetings cut into the time needed to learn the technology of hypermedia and to begin the actual research.

To alleviate this problem, students should have access to the philosophy of history and historiography earlier in their educational experience. This is important not only to provide background for the type of original research demanded by the Civil War course, but more significantly because all students should learn to think critically about historical interpretation, to be less willing to accept historical emplotments that may serve particular historians' needs, and to learn how understanding of the past can be relevant to them today.

Perhaps the site of this experience should be in the junior year survey of American History, where abundant possibilities exist for weaving historiography into the broad sweep of our nation's past. In *Risk and Renewal,* students remarked that the "heart of Dalton's American history curriculum" focused on "great men." Instead, concentration on the disparate historiographical interpretations of the American past, on the semiotic aspects of U.S. history, and on the notion of a shared history that emphasizes the marginalized as well as the "centered", will enlighten all students to historical bias and subjectivity. Through this process all Dalton students will learn to question historical assertion and will be better able to tackle college history and graduate history curricula, which emphasize interpretation and breadth over facts and chronology. With specific reference to the Civil War project, this early exposure to historiography and historians' bias will save valuable time in the process of researching and creating hypermedia texts.

The other pivotal area in which the Civil War Project could expand its educational impact lies in its relevance to national issues and history. In both *Risk and Renewal* and this year's evaluation, students' understanding of the Civil War's national scope and history was not all-encompassing. Perhaps this is explained by the fact that the Civil War's prehistory and history did not occur directly in New York. Although the Draft Riots are an important part of the era and have far-reaching social, political, economic, racial, and class consequences, they are somewhat removed from the main sweep of Civil War history. Accordingly, it is not surprising that students enrolled in the Civil War Project finish that course with a trenchant, in-depth understanding of local history, but a rudimentary knowledge of the broader national picture.

To rectify this, the History Maker project would benefit immensely by more widespread application. It could be offered in all American History elective courses, to students interested in exploring the multidimensional, interdisciplinary paths open for researching about and understanding the American past. For example, given the richness and depth of African-American history in New York City, commencing in the 17th century, and the extent

For example, the *Magical Mystery Tour* was a polished effort which used the primary research to frame an analysis of the riots. It situated specific locations in Manhattan as backdrops for events relevant to the unfolding unrest of 1863. The visual material was carefully blended into the textual, and important links were made that allowed the reader to become thoroughly immersed in the project. It was evident throughout this project that each segment (site) was thoughtfully placed and represented an important fraction of the whole....it is not surprising that students enrolled in the Civil War Project finish that course with a trenchant, in-depth understanding of local history, but a rudimentary knowledge of the broader national picture.

To rectify this, the History Maker project would benefit immensely by more widespread application. It could be offered in all American History elective courses, to students interested in exploring the multidimensional, interdisciplinary paths open for researching about and understanding the American past.

to which that past mirrored nationwide trends, collection and analysis of primary source material would combine the best of the Civil War Project's emphasis on primary research with the additional value of more national import. A project on Malcolm X, for example, would be able to utilize both print and broadcast media materials which originated in New York. Focusing on the local scene in this instance would provide much insight into New York history and race relations in the city, while at the same time allowing students to become conversant with the broader issues faced by the civil rights movement during its active phase.

Other examples, such as the lives of free blacks in Manhattan in the ante-bellum era, African-American migration to the North, and black cultural and intellectual histories, would also be rich in archival material that would lend themselves to hypermedia analysis. Similarly, a course on post-World War II America could offer a research option in History Maker, which allowed students to collect primary materials, both archival print and broadcast media, that collectively provided broad insight into both local and national themes.

Such a project would evolve gradually. During the first several years students would be actively engaged in research and collection. Their task would be to scan into the database relevant primary material, which would create the Dalton Archive. These early pioneers would be asked to provide historical commentary on their findings, as a way of providing the first set of historiographical interpretations on a set of documents. Students engaged in the project in subsequent years would be less responsible for actual data collection (although significant hypermedia material would be added), but would be more challenged to pose varying interpretations of historical events and figures, based on analysis of the existing materials and on what earlier students had said about them. In each student's case, valuable time would be devoted to learning the hypermedia technology, to collecting and assessing primary archival material, and to contextualizing local New York history within a broader national history. Built into the structure of these courses would be exposure to relevant historiographical interpretations, which would assist students in dealing with issues of bias, emplotment, and subjectivity. Again, it must be stressed that this needs to occur throughout all U.S. History offerings.

Conclusion

The Civil War Project has provided a number of pioneering steps which have enabled Dalton students to conduct primary research, analyze historical documents, learn about historiographical debate and historical bias, and become self-actualized researchers. It is now relevant to move beyond the confines imposed by Civil War history to areas of study in which New York history better reflected national historical trends. Students who can study the legacy and local history of Malcolm X, or the fate of the Rosenbergs, will be better able to learn about their local history, while at the same time gleaning vital information about U.S. history in the modern and postmodern eras. Merging local research with national historical knowledge will go a long way to fulfilling the original expectations of the project. It will continue the emphasis on local history and collection of archival material, it will substantially augment historiographical knowledge, and it will provide a more national focus and historical assessment for students probing the past through a microcosmic, localized lens. In sum, the future of History Maker lies in its ability to concentrate on local history, which allows for primary research and innovative assessment, while at the same time permitting wider application to national historical assessments, which significantly increases the knowledge students require to ameliorate today's dilemmas in a better tomorrow.

> *The fear is always that we're going to lose the kids to this tunnel vision, this locked-in vision into another T.V. tube. And we find that when we're most successful in deploying the technology in the classroom, the kids are actually away from the computer more than they're at the computer. If you enter the classroom on a typical day, there is probably a half or a third of the class there; the rest of the kids have fanned out throughout the school to go find things that are necessary for their investigation.*—Luyen Chou, Apple's Imagine series.

Report to the Dalton School on the Development of a Multimedia Navigator: Ben Davis, Massachusetts Institute of Technology, Center for Educational Computing Initiatives, AthenaMuse Software Consortium

Introduction

> The writer should be informed to the maximum about what he is writing.... If a writer is not driven by a desire for the most demanding verbal precision, the true ambiguity of events escapes him. The amorphous does not require accommodation; it simply fills the room (or book) like a gas. He can only abjure words when he has asked too much of them. And at that moment the ambivalent eloquence of the event saves him. When his pages are finished, the reciprocal ambiguities coalesce into a mystery. Mystifications protect power. Mysteries protect the sacred. Any writer whose writing possesses the credibility I am talking about has been moved by the simple conviction that life itself is sacred. This is the starting point.
>
> John Berger, *Keeping a Rendezvous*, New York: Vintage Books, 1991, pg. 217-218.

How does a kind of multimedia precision evolve out of a seemingly amorphous accommodation?

The Dalton multimedia curriculum projects in history, literature, and science are nodes for network development by acting as generators for archival materials. In this regard, reference is a broad appeal "product". By creating archives of their research, users then have access to each other's research and this creates an intellectual community. Given this condition, how can a student navigate as a browser, creator, and contributor? How can a navigation system be created to accommodate this kind of evolving model?

> This kind of "inductive development" of multimedia computing at Dalton is a commitment to ongoing investigation into the nature of educational technology by doing rather than by theory. It is a pragmatic approach that facilitates the users, the students, to be just as important to the functionality of the system as the visionaries. This kind of approach makes everyone a student and a teacher in regard to the way education is perceived in the community.

Perhaps the most overwhelming impression of my visit to the Dalton School and the Dalton Technology Plan was that of community-building, both technically and intellectually. This kind of community-building is occurring both on the micro and macro scale at Dalton. That is, groups of students both generate and model information conditions simultaneously. The classroom activities mirror what is happening to the entire school as the computing technologies are instituted. The dependence on input to build the community from the small study group — the digitizing, linking, and application building and ultimately the archives of information that result occurs at the individual level and only at the collective level as is necessary. There is a consistency that is both appealing as a self-organizing system and as a "mysterious consensus" organism. There appears to be a research effort of a permanently re-organizing nature that is designed by attempt rather than by grand scheme. This kind of "inductive development" of multimedia computing at Dalton is a commitment to ongoing investigation into the nature of educational technology by doing rather than by theory. It is a pragmatic approach that facilitates the users, the students, to be just as important to the functionality of the system as the visionaries. This kind of approach makes everyone a student and a teacher in regard to the way education is perceived in the community. The school once again becomes a community of learning rather than a place to be attended.

> *As telecommunications moves to a digital format it also will be part of this convergence and that means that we'll be able to access open networks, information that sits out in libraries and we will have in effect schools without walls and electronic libraries and that will be very much a part of our everyday life and the education system.*—John Sculley, CEO, Apple Inc., Apple's *Imagine* series.

What is really of interest in a system like this is perturbation. What happens when unanticipated demands are made on such a system and how can those demands be easily accommodated without destroying the spontaneity of effort? How can the unknown be productively encountered, both technically and intellectually? How can the users discover the form of the system without it being completely dictated by the "science of computing" that is usually employed to efficiently predispose such efforts? Can there be design by consensus, by necessity, by discovery? And if so how is this process communicated collectively without a dictatorial proclamation? How can a pedagogical apparatus be evolved from content like archeology, astronomy, American history, or literature? Is exposition an expandable architecture or is it a limited horizon? Is a school invested in computational systems an educational scenario driven by cluster groups in data-retrieval laboratories? Is this democracy in a constant state of becoming?

In this evaluation I will try to illustrate these questions with encounters with a variety of individuals at Dalton and also to contrast this with experiences with the design and development of MIT's Project Athena and its Visual Computing Group with which I have been involved since 1986. Below is a list of individuals from Dalton with whom I met on May 19-20, 1993:

Tom de Zengotita, Co-Director of the Dalton Technology Plan

Robert O. McClintock, Co-Director of the Dalton Technology Plan

Luyen Chou, Associate Director, The New Laboratory for Teaching and Learning

Robert Matsuoka, Network Manager/Senior Design Associate, The New Laboratory for Teaching and Learning

Lou Miele, Network Consultant, The New Laboratory for Teaching and Learning

William Waldman, Software Designer, The New Laboratory for Teaching and Learning

Adam Seidman, High School Technology Coordinator, The New Laboratory for Teaching and Learning

Steven Bender, Jacqueline D'Aiutolo, Warren Johnson, *Playbill Project*, English Dept.

Malcom Thompson, Astronomy

Matthew Nathan, Student, Civil War Project

My intent in this evaluation is to present a picture of the project from a system point of view and raise some questions in regard to the vision of the overall system and the reality of its current implementation.

Dalton Facilities

The Dalton network in its current form is a 16-megabit token ring running Novell NetWare 3.11, NetWare Macintosh, and Appleshare 3.0 servers. Total network storage is more than 8 gigabytes in addition to some networked CD-ROMs. The network has about 120 machines, mostly Macintosh and some 386 and 486 PC systems, the 486 systems acting as network servers. (In a sense, the current servers are much like a "one-room schoolhouse" in terms of scale.) There are approximately 1,000 accounts on the network. The intent is for users to be able to login at any computer and access anything available on the servers. Users currently cannot customize login files in order to create individualized interfaces. E-mail is not available to users currently but can be created through using note cards from the projects. The current archival model for storing information is that it will be "useful someday". The utilities are all multiuser, but there is no simultaneous access. There is access to external networks like Internet through external accounts at Columbia University.

Staff and Faculty Relationships

The role of staff facilitators on the projects is to be both sensitive to subject and sensitive to technology. In many ways they are the meta-teachers. Faculty subject experts are researchers, facilitators are teachers. They must implement faculty design but look forward to see how it effects subject. This is not a well-understood position. I have been in this job myself for over seven years at MIT. I came to this position as a tenured faculty from a college of art. I have experienced both sides of academic life, faculty and research staff. The new technologies blur these distinctions in interesting and sometimes odd ways. The academic staff researcher has access to all of the institution as a study. The faculty actually have limited access to the institution because they are defined by tradition and their disciplines. In order to facilitate education in this situation , faculty and staff have to maintain a peer relationship that encourages collaboration on technical and intellectual exchanges. The staff person is no longer just a technician and the faculty member is no longer just the teacher. They have a symbiotic relationship that must be recognized as a very vital function of the use of technology and education.

The Nodes

Playbill

Much of the interesting discussion with the English teachers centered around the shift from the original visionary approach — open-ended learning access — to the frontline reality of giving students guided access to material at least initially in warm-up exercises that acquainted students with the material and the technology in small modules. Also, it seems appropriate to give individual labs as a test to master the technology. Because of group activity with the technology there is a strong sense of comparative learning. This situation has led to events like the traditional option for students to rewrite a paper for a better grade becoming an object for group assessment where a project done by a team can be redone by a subset of the group for a better grade and then an individual can chose to further refine the project for a better grade. How many of the revisions do you chose to keep? Is revising itself the only criteria for bettering a grade? These kinds of hypermedia events have caused teachers to "modify assignments as you go" in order to take advantage of the technology and keep pace with how facile students are becoming with the material and the tools of the technology.

One such situation occurred when students were given an "electronic notebook". It was assumed that this would be the vehicle for storing and retrieving notes extracted from browsing literary texts. Instead, students did not use the notebook at all for this purpose. They chose to do all their annotation on electronic "note cards" because they were less intimidating as documents. The notebooks appeared to be much too close to a real book, or a paper, and were therefore not suitable for "notes". Most often students would write their observations on the cards and then paste them into the notebook when it was appropriate. This is a good example of user design over visionary design, performance over ideology. It also points up the whole notion of using metaphors from older information structures and simply trying to make them virtual books, or notebooks, or note cards in the electronic form. This issue of metaphor for information structures in new mediums is an entire research project unto itself. The computer appears to be a concrete mixer in this regard. It makes quite literal what we take as symbolic in everyday usage. The page translated to the computer currently looks like a single flat piece of paper in most word processing programs but the computational reality is that the page is a plane of text behind which can exist an infinite number of other pages, including all the pages in a library. Any actual page does represent this condition symbolically of course, but the computer and the computer network make it quite real.

It was quite obvious also that the use of *QuickTime* movies over the network was so slow that it was useless to attempt, a situation that would discourage the students from comparing film scenes of Shakespeare. The solution may be local CD-ROMS of film material or some means of buffering video clips on a dedicated server but this will have problems in terms of multiple access.

The role of software facilitators in these classes is crucial because they must teach the teachers how updates to programs work and constantly be looking for ways to improve performance. A teacher may discover that students are very frustrated by a program that will not allow them to annotate parts of a picture with text. They might want to say what the apple in a painting of Eve means symbolically but no tool exists for outlining the apple and then linking the image of the apple to a text file that explains the image. The facilitator builds the tools for the teacher with a sensitivity to the reason why someone would need this tool for exposition and then must train the teacher how to use it, so they can in turn teach the students how to use it appropriately.

In the case of the Bible literature classes, another interesting user design situation occurs when students are given the option to think of the Bible as a concept rather than a text. By making biblical renderings, paintings and drawings available as a way to "read" the Bible, the authors of the program did not anticipate that students, given the choice between text and visuals, will often go for the visuals as primary resources rather than illustrations. This is compounded further by being able to tag parts of images as well. In a course studying the "Word" it is quite interesting to understand the challenge the technology is making to intellectual assumptions about learning. Who wrote the Bible? The student is invited by the nature of the hyperlinks to keep track of how they proceed as well as what the point of the exploration is. How does it affect the interpretation? Can the map of the path to a conclusion be its own thesis? Does this require more and more resources and interpretation tools? Must all the resources available at any one time be used? Is this process of understanding the structure of inquiry as well as the answer a constant critique of the underlying system as well as the intellectual pursuit?

Civil War

Faculty and student exposure to older efforts in multimedia curriculum (*Archaeotype, Playbill*) has created a frame of reference for design of new projects. The limitless nature of hyperinformation structures allows one to approach a new subject with a sense of oceanic opportunity. In the case of the Civil War Project this "history of everything" possibility seems to have influenced the nature of the project. Realizing that attempting to create a large database on the entire war was an inappropriate scale given the available time and resources, the scope of the project began to narrow to a functional core project. The scenario seems to have gone from the Civil War to the North in the Civil War to New York in the Civil War to New York City in the Civil War to the Draft Riots in New York City in the Civil War that occurred for four days after the July 12, 1863, announcement of the names of New York's first draft. This zooming into a historical event based on the perceived ability to do everything is a very interesting consequence of understanding hypermedia. This kind of critical thinking is very important both to technical development and its effect on a community.

The Civil War Project then has a new identity as a localized event that has important historical links to the start of the war as well as to the end and aftermath of the war. It also allows the student to collect information and build links to other information in an unbounded way from a core event that is specific in place and time and has relevance to the experience of the student. The walking tour of New York City puts students into the field for data collection and also orients them to seeing familiar surroundings as historical markers. Unlike *Archaeotype* and *Playbill*, the Civil War Project is not a set package but a system for user-created projects revolving around a common event. The students are put in the position of deciding what resources are necessary for defending and navigating an intellectual proposition. The resulting archives of propositions transferred to a CD-ROM create both a package of exportable materials and summary of user data and systems of creation.

Doing this project as a seminar elective also raises the question of whether an "elective" is more central to developing a style of scholarship than "core curriculum" in terms of using computing technology as a learning aid. Has the peripheral curriculum moved to the center because the technology is capable of expanding the dimensions of subject that a student elects to take because of a personal interest rather than being required to? Could all subjects be electives? Deciding on a topic, a scheme of information gathering that includes interviews, libraries, walking, photographing, putting the information on-line (scanning, editing, authoring), and then creating a presentation scheme for expository correlation and communication would seem to be a fundamental procedure for study, a procedure that ordinarily comes in advanced stages at a university.

The attendant problem with the making of archives of these materials (picture, *QuickTime*, text, and project-use archives) would seem to be another seminar elective in itself, like creating a multimedia card catalogue. This almost seems an advanced library science problem that would require a committee of librarians to decide what should be kept, what is redundant, and what should be discarded. The intention of creating these archives for future groups to use as resource materials will create a number of technical and editorial problems, least of all describing somehow the context from which the material came and finding room for increasing amounts of motion video and sound linked to text as interview material increases.

Archaeotype

The technical improvements since I last saw *Archaeotype* in early 1992 are impressive. The use of color graphics and color digital photographic images give the project a heightened sense of realism. The continued development of this project is especially important in keeping it a constant among the projects at Dalton. The key issue of using the metaphor of information excavation is an important tutor for multimedia design. Information is literally unearthed. It is encouraging to see the project continuing to go grow technically and to retain its place as a multimedia curriculum that teaches history, historiography, science, and applied mathematics—as well as adventure. My only suggestion would be to create aspects of it more like the Civil War Project where students design the historical events as well as the excavations.

Astronomy

The Astronomy class reminded me that the word "consideration" comes from the Greek "with the stars". The class indeed seemed to be considering the digital availability of astronomical information from a variety of commercial and academic packages. The image analysis tools and data readers available in the classroom seemed to create tasks and challenges that were both doable and complete-

> *Kids in our* Archaeotype *class are able to use the Louvre Museum as essentially an extension of their own library. And that's creating an environment where kids are increasingly going to be able to make the kinds of discoveries that, up until now, have been reserved for scholars to make.... What schools are increasingly, are watchtowers with windows out onto the same world....And the digital technologies are going to provide those windows of access to a common universe. And schools and educators have to begin to prepare for that. That's an inevitability.*—Luyen Chou, Apple's *Imagine* series.

able in the context of group work at the machines. It was the only classroom environment that I visited; the students seemed to be completely at home with using their computers in groups while allowing different individuals to handle the controls. The teacher at one point held up the paper worksheet that a group had turned in and said "What, only one sheet for everybody?" To which the students replied "It's a group project!"

These nodes then: *Playbill*, Civil War, *Galileo*, and *Archaeotype*, generate a substantive body of scholarship. They are the beginnings of a network of ideas that must be stored and retrieved on demand. As other subject nodes are created the ability to access and utilize them will become extremely important. The specialized tools these nodes have created for annotating, linking, and correlating ideas (ideas that may be represented with text, audio, images) will need to be reused and modified for new disciplines. How will the user know where to find these banks of information? How will they know where the tools are or how to use them? How can they avoid recreating projects and tools that are already available? How will their work find its way to the electronic library? How will they communicate? How will the system be secure?

Network Navigator

The construction of a network Navigator for the Dalton System would seem to have to fit a number of needs. It would have to be considered by users as a cultural mechanism that would impart a conceptual sense of community (much like the way an archeological dig forms a nexus of physical work and intellectual pursuit), would encourage users to enter and exit the system responsibly, would provide tools for archival creation and extracting data of all types, and would make available tools and systems for articulating group and individual projects. In short, the Navigator would reflect the curriculum nodes already in place: history, literature, and science. It should demonstrate a kind of "ecology of information" that the system presents.

The history projects like *Archaeotype* and the Civil War represent archival and extraction schemes that are place-based. These projects metaphorically reside on the "sense of community as cultural mechanism" side of the scheme. The science projects coming in would seem to be more on the "data analysis side", analogous to computing mechanisms that maintain the technical integrity of the system, and the literature nodes would seem to be related to "articulation" tools of all kinds. These conceptual models interconnected form the fundamental blocks necessary to create a working laboratory for interdisciplinary study.

The Navigator mechanism would then be a generic overlay that would take tools and systems that have worked in the projects and elevate them to common pedagogical functions. The danger in creating a Navigator mechanism is that it may damage the sense that the use of the technology is an experiment and that there is no "ultimate voice" behind the system like the Wizard of Oz. The Navigator might be another curriculum project in "systemic thinking" that students put together as an experiment that is re-created periodically in order that it not become gospel.

What then are better integrated tools for the computing environment? What is the user's image of the system? Is it based on mythology, on pictures, on the technical reality? Is the Navigator a person, a thing, or a system? Can it be customized, therefore making it a personal navigator? Or is it something like the Zen concept of the non-navigator, someone who guides by offering paths but no maps? More of a process than a product?

Currently the network at Dalton has "simple systems' advantages" in that there is not so much traffic and storage that collective decision making on what is valuable is still possible. The community of information and information users is still small enough to make immediate changes communicable. This will certainly change over time as more and more information and more and more users are added to the system, including connections to outside networks. Added to this is the sense that any utility created has to be engaging enough for a high school student who will lose interest if the system is slow and unresponsive. Currently, a sense of community comes from all folders being accessible to other students on the network.

There are a number of substantive research questions:

Can a culture at large be responsible for tagging pieces of information for archives and if so what does the tag look like? For instance, are the simple information fields on current card catalogs adequate for video sequences that are used in a particular context? How does the community arrive at the proper number of items for a card in this system?

If information is taken out of context from different projects and put into general archives what community decisions must be made and how are those decisions acted upon? Can a community come to a decision that this video clip is of a recreation of the draft riots in New York during the Civil War, a biased dramatization, or a distorted use of a commercial film about rioting in 19th century New York that the author of the multimedia piece has used without permission?

What about the integrity of the information in context; how is that preserved? This could create an ambiguity of ownership. Whose "voice" is attached to the information? Prescriptive descriptions for cataloging the context might be a solution, creating a "culture of referents". The process makes concrete current artistic concerns like "decontextualizing, deconstruction, and appropriation". For instance, a number of different people use an image of the American flag and then refile it as a symbol, a political icon, a national identity, and a garment (from the sixties). How is the voice that does the categorizing tagged?

How can these archives be constructed to preserve serendipity? New ideas often come out of looking in places that don't make sense, like the book of shelves just above the one that is supposed to have the book you're looking for. And on that randomly accessed shelf is just the title that makes your entire thesis valid. Or when you are flipping through a particular magazine and the picture next to the article you were searching is the face of someone who looks exactly like your eighth grade teacher who told you something that is exactly the key to the whole question of your research. How can you browse around in a system this way when the system is rigidly organized to dispense information in logical bits?

Is the situation analogous to newspaper or advertising agency archives? Is the only comparable example the old paper archives where all kinds of information are literally stuffed into drawers and rely heavily on the librarian or archivist who has been doing the stuffing for years to find what you need? Should the Navigator be thought of as a person with a photographic memory but capable of blurring content? For instance, you ask the Navigator for all the photos of men with beards and it does so, but also asks if you want to see men with boards too, and shows you a sample of Lou Costello swinging around that 2' x12' that's going to whack poor Bud Abbot?

It is ultimately the problem of creating group resources as well as individual resources? When a group of students produce a project, the materials are catalogued in one type of context. When an individual goes to the library and extracts materials and uses them in a project, do they file them back with the group's project or make a new card for them?

Systems and Tools

The problem seems a bit like building a multimedia codex, something between curriculum and a database. Curriculum must be easy to create and add to the codex. The image of a user is someone who comes to the network to do interactive construction, presentation, and evaluation. The suggestion of "grab bags" or tools for creating collections off the network is ultimately a kind of dynamic bibliography with a "Desktop" syntax. With the intention of reusing materials, the database would seem to have to be object-oriented in order to store media modules that have been annotated in a variety of ways.

This kind of multimedia library would require group files, personal accounts, and a card catalog with a dynamic axis, as well as Internet connections. Tools for the card catalog would require browsers for motion imagery with sound and picture, picture browsers, text browsers, linking tools to interconnect digital still images, digital motion imagery, digital sound imagery, text, and applications launchers. The database for this would have to be both relational and object-oriented and seemingly would allow users to leave material in a buffer for inclusion in the database after some kind of librarian approval. Keywords, thumbnail images, movie previews, and sound bites would have to be available in browsers as well as descriptions of location, medium and Library of Congress annotation.

Will a librarian be required to scan the network and determine what is not cataloged, what collections will be timed out, what preservations will have associations? What are the authority issues?

What is the criteria for determining what remains in the archives and what must be discarded?

Storage of information is not infinite. Each annotation to a piece of information takes up more space. A multimedia database is not a trivial problem in computer science. Little is known about how to partition multimedia data. The decisions about how storage is allocated and used are paramount to a system that is geared for easy input and output.

Will students feel monitored, inhibiting associations? Suppose I am trying out a proposition and just want to try out a few pieces of information to see if I can get an idea going. Will the system keep track of what I'm doing? Will someone else be able to track what information I put together and then discarded? Will they be using my trail to develop an idea that I had but didn't have time to complete? Will I see my exploration as a finished project?

Would projects on redundancy and image resolution destroy the system? Just for fun, to test the storage capacity of the system, I could decide to make the topic of a report about where the term "redundant" came from with thousands of examples of how a piece of data can be permanently saved by making millions of exact copies of it. Or maybe I will show how a single image can be used to measure the resolution of detail to the nth dimension—save all the copies of the image with minor changes in resolution.

What are the external use issues regarding remote logins? What are the legal issues?

Can parallel development of a client/server structured database and stand-alone prototyping occur smoothly without causing the system to disfunction? Can a part of the system be allowed to be used as an exploratory development system while the rest is used in day-to-day operation without compromising the access to materials? This is a tricky problem that will require a good deal of budgetary investigation. How big does the model system have to be to get a good idea of the conversion of the entire system?

Will the user be creating a micro version of the system every time they create or collect something?

Will students be creating a multimedia syllabus?

Recommendations

As Dalton moves from what has been primarily an educational inquiry into the nature of student reaction to computing technology into an inquiry into the nature of systems thinking and the kinds of models available for enhancing more and more complex interactions with the nature of education, it becomes important to look at more sophisticated systems designs. The systems created by MIT from 1983-1991 at Project Athena are interesting in that they were built as a systems investigation rather than an educational experiment. Educational experiments were constrained by computer science imperatives in this case. The system that resulted is worth looking at, however, because it did create a computational mechanism that addressed many of the questions and issues raised in this evaluation.

Parallels in the Athena Network System

The description of Athena's components is useful to Dalton because it identifies a number of services that appear to be required for systems approaching 200 workstations (Dalton is currently at 120 systems and growing). I offer also a brief description of the Athena Dashboard which is a very minimal graphical navigation interface to Athena that embodies some of the characteristics that might appear in the Dalton Navigator.

Project Athena was originally designed as a UNIX-based scalable, distributed workstation environment intended to operate twenty-four hours a day and accommodate heterogeneous hardware. Dalton may never become this large but it will be used twenty-four hours a day at some point and it will certainly be used with remote computers.

The Athena system is client/server based which allows any user to go to any workstation and access files and applications without finding any differences in the user interface and service delivery. The system is secure, location-independent, centrally administered, and relatively easy to install and update. A user needs only to logon with a user ID and password and the system services recognize and authorize the user to enter the Athena environment. This appears to be the goal of the Dalton system.

Project Athena also produced X Windows, Kerberos (an authentication mechanism), Moira (service configuration management), Zephyr (on-line notification), Hesiod (name server) and Palladium (print services). Project Athena relies on MITnet which consists of a 100 Mb/sec fiberoptic FDDI (fiber distributed data interface) extending the length of the MIT campus. The spine has no systems directly attached to it but has routers to subnets. MITnet is connected to NEARNET (New England Academic and Research Network) which is connected in turn to NFSNET (National Science Foundation Network). Dalton has already created some software tools and will certainly use or create more as well as be connected directly to external networks.

Project Athena manages about 1500 systems out of these 4000. It has 1300 workstations, 80 file servers, 40 print servers, and 125 associated printers and accounts for over 50% of the traffic on MITnet, which is partitioned into 40 Ethernet 10Mb/sec subnets. Every subnet has at least one system software delivery server. Only boot and communication software is kept on individual workstations. The subnet servers provide most of the system software on demand, and have the binaries for each type of machine present on the subnet.

If subject-oriented nodes like *Archaeotype* or the Civil War at Dalton continue to accumulate information, a central network with subnets will have to be considered to deal with traffic accessing and processing data, especially picture and sound data.

Ninety-eight percent of all undergraduates have accounts on Athena and about 80% of graduate students. I assume that ultimately 100% of Dalton faculty, students, and staff as well as external researchers will have Dalton accounts.

Athena initially adopted the Network File System (NFS) from Sun Microsystems. It has migrated to AFS (Andrew File System) from Transarc Corporation (originally from Carnegie Mellon University) for file management and back-up. Athena also uses RVD (Remote Virtual Disk) developed at MIT to provide read-only binary service to each subnet. The subnet RVD contains the code for operating systems on a particular subnet. User files, courseware, and licensed software are stored on the file servers in "lockers", hierarchical directory structures. Students are given 1.2 Mb of backed-up file space but can get more on reasonable request. The total amount of backed-up file storage on these servers exceeds 40 gigabytes.

Applications like authentication or on-line help are consider a service on the network.

Services are centrally administered but are physically located strategically to have low impact on users should parts of the network be down. Central services include the authentication system Kerberos which requires an encrypted password from each user that produces encrypted "tickets" valid for a specified number of hours that allow the user access to the network. They can "renew" the tickets at any time to remain on the network. The system is based on the "trusted third party" model.

Once a distributed environment reaches more than 200 machines it becomes economical to install and update client-server software from a central service. Moira is the central management facility that uses a relational database of all system control and configuration data. It holds data on files, users, services, hosts, mailing lists, and group lists. Changes to the database are communicated as service-specific configuration files to servers on a regular basis. The Hesiod server is the system that goes to Moira for the user's customized login files. When users log onto any workstation, Hesiod associates them with their home directory, translating logical into physical addresses, and giving the user the illusion that any workstation on the network is a personal workstation complete with customized interface.

Other services include the Post Office servers that store and forward mail. It must be stored and forwarded because the user can login anywhere and ask the Post Office to send mail to the particular workstation where they are. Zephyr allows Zephyrgrams to be sent to users or groups of users currently logged on like small telegrams. Users have the option to subscribe to different classes of Zephyrgrams (system announcements, etc.) or not, depending on whether they want the messages to appear on their screens. OLC or On-Line Consulting is built on top of Kerberos, Hesiod, Zephyr, and the Post Office and gives the user the opportunity to instantly get help from a group of consultants or from a list of stock answers to familiar questions. The On-line Teaching Assistant gives students direct access to the teaching assistants for the courses they are taking. Dialup service is provided by a number of workstations configured to interface with the modem pool of the MIT digital phone switch. These calls are then routed onto the MITnet Ethernets where any available dialup server is assigned. Any terminal emulation program for Macs and PC can be used.

Discuss is an electronic conferencing server that allows users to set up public or private meetings and provides authentication, moderators, mail archives, and transaction flags. On-line Documentation is accessible through menus or keywords and is carefully maintained in hierarchical modules. Map-based applications like Xcluster display maps of the campus whixh are hyper-text based graphics that show what machines are free for student use, what type of machine it is, and how many are already in use. Global messaging can be used to send messages to classes of users such as alerting all freshman to new course offerings. Printing is available as a quota (1200 free pages per year) and paid printing for any amount over that. Printing is location independent and authenticated.

An average of over 100 courses each semester now require the network. Initially the network usage centered around word processing, electronic mail, simulation, and games. Currently usage has shifted to scientific modeling, visualization, and courseware use by students. The current organization maintaining the Athena system falls under the general administration of the MIT Information Systems that oversees all of MIT computing infrastructure.

Project Athena's organization is now composed of staff working in faculty liaison to develop and maintain faculty-generated courseware initiatives, third-party software acquisition and support, authoring tools and support, productivity tools like spreadsheets and word processing, management of user accounts, consulting for on-line help, training, documentation, customer service for hardware maintenance, system server support, release engineering for operating system updates, and software engineering. In addition administrative support is required for budgeting, inventories, and contract negotiation. As the system at Dalton expands, some modified combination of these kinds of positions may be necessary beyond the current system manager and facilitator roles.

Athena Dashboard

The Athena Dashboard or Dash is a single command bar that automatically appears at the top of an Athena workstation upon login. Eight categories are displayed on the bar as well as the current day of the week, month, day, time, and year. The eight categories are pulldown menus. All that is necessary to launch anything contained in Dash is a mouse click. From left to right they are:

1. Dash (About Dash, How to Use Dash Menus, Screen Accessories—which has a horizontal pullout menu with a list of desk top accessories like calendars, calculators, etc.), a list of command buttons for hiding Dash, etc., and a Quit command.
2. Help contains information on Campus Emergency, MITnet, Athena, and other computer help.
3. Courseware contains About Courseware, information on connecting to course TA's, NEOS (an electronic technical writing module), and fourteen courseware offerings ranging from Civil Engineering modules to Dartmouth Northware. All the courseware entries have pullout menus for explanation of courses.
4. Communication contains Mail, Discuss, NetNews, and Zephyr.
5. Text/Graphics contains word processing programs and a variety of graphics editors.
6. Numerical/Math contains analysis and plotting software and spreadsheets.
7. Programming includes access to supported languages, unsupported languages, debuggers, toolkits and libraries.
8. Special contains Announcements, new software, new xterm window, send bug report, Tech Info (on-line campus newspaper), Student information services, hardware hotline, and MIT Libraries which connects to Barton, HOLLIS, and a number of libraries in the US on the Internet.

The design of Dash is intentionally generic and it can easily be removed from the user interface and re-invoked when needed.

There are currently two texts on Project Athena that might be of some use to those concerned with designing the Dalton navigator:

George Champine, MIT Project Athena: A Model for Distributed Campus Computing, Digital Equipment Press, 1991.

Matthew Hodges, Russell Sasnett, eds., Multimedia Computing: Case Studies from MIT Project Athena, Addison Wesley, 1993.

Future Directions

The construction of the Athena System was of course designed for a much larger campus. The fact remains, however, that once a certain number of machines are connected together, services and maintenance become problematic. The intention to capture, store, and retrieve multimedia information that Dalton suggests is a problem that Athena has not addressed in any direct way. The system requirements at Dalton, although smaller in scale, may be equally as large as Athena in terms of data storage at the present time. This is now the time for Dalton to look closely at systems like Athena for the key components necessary to maintain an attitude of precision information usage.

> By creating archives of their research, users then have access to each other's research and this creates an intellectual community. Given this condition, how can a student navigate as a browser, creator, and contributor? How can a navigation system be created to accommodate this kind of evolving model?

Dalton's intention to create a Navigator software suite implies that the system is getting close to being large enough to get lost in. The time to begin planning and building a coherent, scalable system architecture is soon approaching. The alternative being to keep the system from growing and expanding beyond a certain limit. This limit on a multimedia network is very difficult to determine because the use of the system generates larger and larger amounts of data. Athena currently stores no motion imagery and very limited digital still imagery and has not begun to address these issues in any substantive way. The MIT Center for Educational Computing Initiatives is just beginning this year to create image servers for its own subnet as a test bed.

Dalton, therefore, is in an excellent position to do leading edge multimedia network implementation on a manageable scale. The creation of the Navigator software would be an important application to develop as the system is formalized and implemented. The current thinking on this system places a card catalog system as the central file system. This central repository is linked to the various nodes through a collection item filter that would allow the user to browse collections based on collection item descriptors. The user might want to look for collections of images from the Civil War for instance and ask for them by date, location, etc. The card catalog would also allow itself to be browsed by topic through a topic item filter. In this scenario the user could look for Draft Riots, Civil War, by hierarchical topic links. Also associated with the card catalog would be user tools and card link tools that would facilitate making applications. This scenario allows for the making of exposition materials but would limit the creation of more interactive, open ended activities, the "what if" type of scenarios that will surely evolve into educational experiences like simulations. What if the draft riots had occurred earlier or later, what if the draft riots had influenced the central government to stop the draft, etc. This kind of scenario would require more and more sophisticated database access and entry tools. The Navigator then would have to be designed to allow for future expansion of the system into the realm of simulation as well as exposition. In this case, relational, object-oriented links and linking tools would need to be employed to pull data and enter it into flexible spreadsheets like templates.

It would seem very appropriate for The Dalton School to create projects of collaboration with outside groups that could exchange technical expertise as well as on-site people to facilitate a clear, ongoing picture of what is available and useful in information networks. It would be important for Dalton to have the best consulting information possible at this time in order to fully understand the potential and trade-offs of network design.

Proposed new projects at Dalton like the collaboration with the Brooklyn Museum for a new *Archaeotype* that utilizes Egyptian antiquities, the creation of new excavation tools that may be disseminated, CD-ROM snapshots of projects and student work for demonstration, evaluation, instant publishing, extending the Civil War to a southern school, and the continued publishing of performance documents will increase the exposure of the outside world to what Dalton is attempting as well as exponentially create more data to be stored and navigated.

The issues of context, content, ownership, communication, and the use of historiography as interface design subject for navigation systems are all substantive research problems that will require exchanges with a variety of audiences with varying degrees of technical and intellectual expertise. Among these will be internal Dalton faculty, staff and students, parents, alumni, corporations, and other educational institutions and organizations. Issues will constantly be raised over actual classroom experience and theory.

The system will be in demand externally from schools attempting similar projects. Dalton will have to scale internally to meet its own demands. And ultimately the appropriateness of the experience will have to be constantly evaluated and adjusted if the experiment is to have longevity. Added to this is the ability to say no to technical developments that may actually interfere with educational aims even though they may provide some technical efficiency or some market advantage.

***

Part II Collaboration and Dissemination

1) Introduction

If it is to succeed in the long run, the *Dalton Technology Plan* must be responsive to the larger educational environment. We must *collaborate*, and we must *disseminate*. There are two fundamental reasons for this: first, the nature of the enterprise is extensive; its promise is realized as the resources of other institutions become available to our students and faculty by way of networked media. Second, to the extent that the strategies and projects developed at Dalton prove to be transportable to other, perhaps less favored, educational settings, the *Plan* will be increasingly recognized as a source of solutions to some of the desperate problems at the center of our national agenda. Such recognition will be valuable, not only because it will testify to Dalton's continuing commitment to progressive values, but also, and quite practically, because it will inevitably lead to substantial support for further development.

> *The fact of the matter is, digital technologies are already as pervasive as the printing press and therefore its almost as foolish to say that I don't want to have anything to do with the new digital technologies as it would have been a hundred years ago to say I will only work with handwritten manuscripts.*
> Frank Moretti, Apple's *Imagine* series

The documents and discussions in this section illustrate the developments and possibilities in this area—most dramatic is Professor Dodge's evaluation of the use of *Archaeotype* at the Juarez-Lincoln school in Chula Vista, California. But it is no longer possible, especially since Dalton's three-day presentation to the New York State Association of Independent Schools at Mohonk, to describe all the collaborative relationships we have with other institutions. Professor McClintock has chosen to describe a sample of those archival, educational, and corporate connections which have been most deeply cultivated. We also offer two examples of the kinds of proposals we will now be in a position to make more often and more credibly as the evaluation process discussed in the previous section continues to unfold. Finally, Professors McClintock and Taipale offer an outline of the larger historical context within which our efforts are necessarily situated, and which we must perforce take carefully into account.

***

Collaborations 1992-1993

Robert McClintock

Schools teach subtle lessons. The narrow view is that a school such as Dalton should concentrate solely on its students, leaving educational leadership to others. The educational message of such a position is narrowing; it establishes George Bernard Shaw's quip — "those who can, do; those who can't, teach" as defining policy of the school. The message to the young is far more inspiring, educative in its fullest sense, when the school itself engages in efforts of leadership and productive change. Thus, collaboration and dissemination activities become part of the central educative program of the school.

Part of this effort at dissemination and collaboration consists in a wide range of cooperative arrangements for a variety of specific purposes. These arrangements bring resources, human and technical, to the school and help us exert influence in the world of education. Here are highlights for 1992-93.

The New Laboratory as a Test Site

As a test-site for Avid, a computer software company based in Massachusetts, Dalton tests such products as the DiVA Videoshop 2.0.

Over the summer Dalton came to an agreement with Supermac. Supermac, a company that specializes in video editing boards, will provide the New Laboratory with their product, which will allow students and faculty to take videotapes and directly digitize them, thus allowing for use of the videos over the network and in individual projects.

This past year has also included testing of IBM's *Columbus* and *Illuminated Books and Manuscripts* series.

In the Spring of 1994 Dalton will become a test-site for the "Search For Justice" CD-ROM which is a multimedia-based curriculum developed for Time Warner's Court TV. The program, which focuses on the Rodney Glenn King case, will be used in the upper grades at Dalton.

Consulting

As part of the expansion of Sundance, a software company based in Massachusetts, Luyen Chou, the New Laboratory's Director of Operations, has become a member of the company's advisory board which looks at technology-based curriculum projects.

Several members of the New Lab staff have worked with the Lucas Educational Foundation on their project to develop a video series on the future use of technology in education. Luyen Chou, Robert McClintock, and Frank Moretti have on different occasions spent daylong sessions contributing to the project.

School Partnerships

Over the past year the Independent Schools Association of Central States has asked staff from the New Laboratory to act as consultants looking at the possibilities of the future use of technology and education. As well as consulting, the New Lab has offered teacher training workshops for the ISACS. In the Winter of 1994 members of the New Lab will present the Dalton Technology Plan at the ISACS Headmaster's Conference in Chicago.

The New York State Association of Independent Schools enjoyed a demonstration of the Dalton Technology Plan at its annual conference last November and then follow-up teacher training workshops at Dalton in the Spring.

In the New York area, the New Lab helped Sacred Heart Academy to design a strategic plan for the integration of technology into the curriculum and offered training sessions at their site. Consultation and development of a technology lab at Boys Harbor, an educational and social service agency, has begun with future plans to connect the Dalton network and an e-mail system to the Boys Harbor site. Also in the New York area, the New Lab led workshops this past summer for the WNET Teacher Training Institutem, and members of the Dalton faculty provided their services in a program arranged by Solomon Brothers where weekend workshops are given to public school students.

Other school collaborations include the Pomfret Academy in Connecticut, where consulting and presentations have occurred; The Wellington School in Ohio, where in the Spring of 1994 *Archaeotype* will be launched; and the Juarez-Lincoln School in Chula Vista, California the original test-site for *Archaeotype* and the site for future collaborations. In a recent attempt to have the fifth graders at Dalton partner with children in different communities, the Lake Minchumina School in Alaska has set up an e-mail system allowing students to directly communicate and share their experiences.

University Collaborations:

Cornell University has joined forces with the New Lab in the testing of CUSeeMe and talks are under way to expand the connections between the two institutions. University collaborations have been also been extended to include the MIT Media Lab with whom Dalton is currently testing Video Streamer software developed by Glorianna Davenport and the Interactive Cinema Group. As part of the Chula Vista collaboration, San Diego State University helped the New Laboratory by conducting the first evaluation of *Archaeotype* in a setting outside of Dalton. Dr. Bernard Dodge was the evaluator in charge. Coming in the Fall of 1994 the New Laboratory will be working with NYU to provide courses using the new technologies in the Continuing Education program. Columbia University and Teachers College are developing an extensive effort to collaborate with the New Lab to bring ideas about the potential uses of technology in education to bear on higher education and on a much wider circle of institutions. The strategic plan developed by the Institute for Learning Technologies, which is reproduced below, describes these aims more fully.

Cultural Institutions

In an effort to expand the collaborative relationship between the Metropolitan Museum of Art and The Dalton School, former Dalton student Ben Mandel consulted and developed the kiosk component for the education department to be used in the upcoming Art of Medieval

Spain Exhibition. Used for visitors at the entrance of the gallery, the program allows users to inquire about artifacts in the gallery and gather information about the time period.

As part of the New Laboratory's effort to disseminate information and projects developed at The Dalton School, The Brooklyn Museum has agreed to become a partner in the expansion of *Archaeotype* into the public schools of New York City. The museum will provide its digitized Egyptian collection to be used as artifacts in the excavation as well as the original site plans from its archaeological site in Egypt.

* * *

Collaborations provide important feedback in the conduct of a project. Dissemination enables those creating the project to assume a reflective distance, seeing it in a novel setting, conducted by others who are not familiar colleagues. Such distancing provides a proof of concept and invaluable feedback. The most extensive instance during 1992-93 was in the Chula Vista project, reported on at length in the contribution by Professor Dodge below. In addition, observers provide essential feedback in the form of letters that provide immediate perspective on our efforts and in the form of articles published in technical and educational journals. There follow two letters that indicate the sort of feedback we receive.

Letters

From the Provost of Columbia University

Columbia University
Provost of the University
October 17, 1992

Dear Gardner,

I've had an opportunity to take a close look at the summary of the first annual report of the Tishman Family Project. A number of reactions and observations:

(1) It is important, exciting, badly needed, and only a few years in advance of what will become standard in the better secondary schools in the nation.

(2) The substance of the project is, to use what is rapidly becoming a cliché, at the cutting-edge of thinking about the relationship between the revolution in information technology and the presentation of basic substantive, educational materials.

(3) You are moving your students and faculty away from the 19th century modes of instruction, where teachers (usually at the head of a classroom) impart knowledge or extract it through lecture or dialogue, to a new multidimensional methodology of instruction. The network and structure that you are developing will open up new possibilities for exciting learning processes. New forms of interactions will become possible among teachers, students, data bases, as well as students and teachers located at more remote sites. Every classroom that is built or renovated, whether for a course in 17th century English literature or 20th century molecular biology, should have the capacity to use information through integrated networks and data bases of the kind that you are building. Moreover, your project does not substitute machines for people, but augments the possibilities for both teachers and students to confront each other and source materials in new ways. And that is much to the good.

(4) Along the same line, the development of this resource will enable students to be creators of knowledge—to be engaged in "problem finding" as well as "problem solving." This is important since learning to ask a good question for which there is no existing answer is often as important as solving a puzzle for which there is an answer at the back of the book..

(5) The project fosters a critical posture for students. As one of the students pointed out in a wonderful passage on the Civil War Project all of us have our biases and presuppositions. Teaching students how to take an intelligent critical position toward the materials they confront—from "facts" in textbooks to reported "facts" in the media is essential to students developing a critical and analytic point of view, to say nothing of developing a thoughtful and well educated citizenry.

(6) The linkage to college and university advanced technologies is the most impressive I've seen.

I could go on at far greater length, but I've got to catch a plane for a meeting at Harvard, where I will take up the matter of admissions criteria about which we spoke at our enjoyable lunch.

Two final points. First, I realize that there may be some anxiety about the investments you have made in this project when there surely are many unmet needs at Dalton and when it must be clear that resources of this magnitude could be spent usefully on furthering many traditional educational goals. However, despite that possibility, I believe, without reservation, that you have made the wise and bold choice and that it is the correct one. This project will yield huge dividends in the future, solidifying Dalton's position as one of the very best and most innovative schools in the nation. Taking a somewhat longer perspective, I believe almost everyone will come to see that you are establishing an infrastructure that will be a necessary condition for extraordinary educational experiences, that you are improving teaching skills and methods, and that you are quietly changing the local culture in a positive way.

Second, there are a number of colleges and universities that are working on educational projects that are similar to yours. One is at Carnegie Mellon, others at MIT, Stanford, Columbia, among others. I'd be happy to discuss those efforts with you, but you might consider making a "field trip" or two to see what is being done elsewhere. You'd find it worthwhile.

Congratulations to Dalton, to the Tishman family for supporting this innovative project, and to you for taking the lead.

See you at the next Board meeting.

Sincerely,

Jonathan R. Cole

From the Executive Director of the Lucas Educational Foundation
The George Lucas Educational Foundation
20 July 1993

Dr. Gardner Dunnan, Headmaster
The Dalton School
108 East 89th Street
New York, NY 10128

Dear Dr. Dunnan:

I am pleased to write in support of the work of the New Laboratory for Teaching and Learning. During the course of the past couple of years, I have had the opportunity to not only visit the New Lab, but to have Frank and Luyen participate in the work of this Foundation. Their insights and experiences in the areas of teaching, learning, and technology are quite profound.

The work of the New Lab in interdisciplinary curriculum, technology integration, cooperative learning, and staff development is really in the forefront of much of the work that is being done in this country. Even though the approach of the New Lab is a more difficult route to take, it is the appropriate one if we expect our students to be active thinkers and problem-solvers. The *Archaeotype* program is an excellent example of what terrific interdisciplinary interactive multimedia software can be! I hope the Dalton School is contemplating a marketing and distribution strategy.

As this Foundation defines the vision and determines the content for the series of dramatic videos we are developing that depict a technology-rich educational system of the future, Frank and Luyen have both been extremely helpful in providing useful and practical information based on their innovative work at the New Lab. I appreciate their time and their knowledge!

Best of luck as you continue another year of this very important work.

Best regards,

Patty Burness

Executive Director

The Dalton Technology Plan Disseminated: Archaeotype at Juarez-Lincoln:

Bernard J. Dodge, Ph.D., Principal Investigator, Jennifer Segars, M.A., Research Assoc.
Educational Technology Department, San Diego State University

Background

One of the first tests of an innovation is its transportability. How was *Archaeotype*, developed for use in a New York City school for children of the upper middle class, implemented and received in a very different setting? That is the question addressed by this report.

Goals of the Study

There were five overall goals of this study which can be phrased in the form of questions that guided our actions:

1. How was *Archaeotype* implemented at Juarez-Lincoln School?
2. What did students learn from *Archaeotype*?
3. How did students and teachers feel about the program?
4. What differences are there across groups in learning and affect?
5. How did this implementation of *Archaeotype* compare with the previous year's coverage of the same topics?

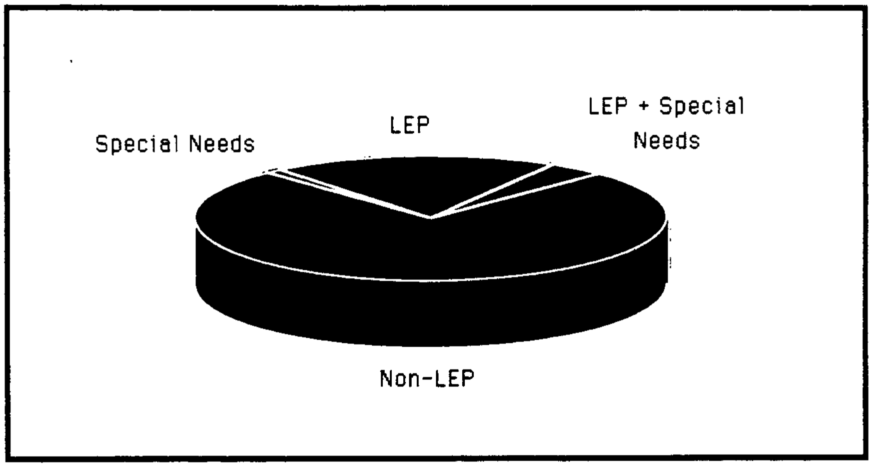
School Population

Juarez-Lincoln School is located in Chula Vista, California, a city of 140,000 located between San Diego and the Mexican border. The school has 614 students who come from working class backgrounds. Ethnically, the school population in school year 1991-2 was as follows:

48.9%	Latino/Hispanic
22.0%	Caucasian
19.2%	Filipino
6.8%	African-American
2.9%	Asian/Pacific Islander
.2%	American Indian/Alaskan

Archaeotype was implemented with three sixth grade classes at Juarez-Lincoln which had a substantially lower proportion of Caucasians than the figures given above. Among the 89 sixth graders who experienced *Archaeotype*, 21 were classified as LEP (Limited English Proficiency) students, and 4 were identified as having special needs, of whom 3 were also included among the 21 LEP students.

Implementation

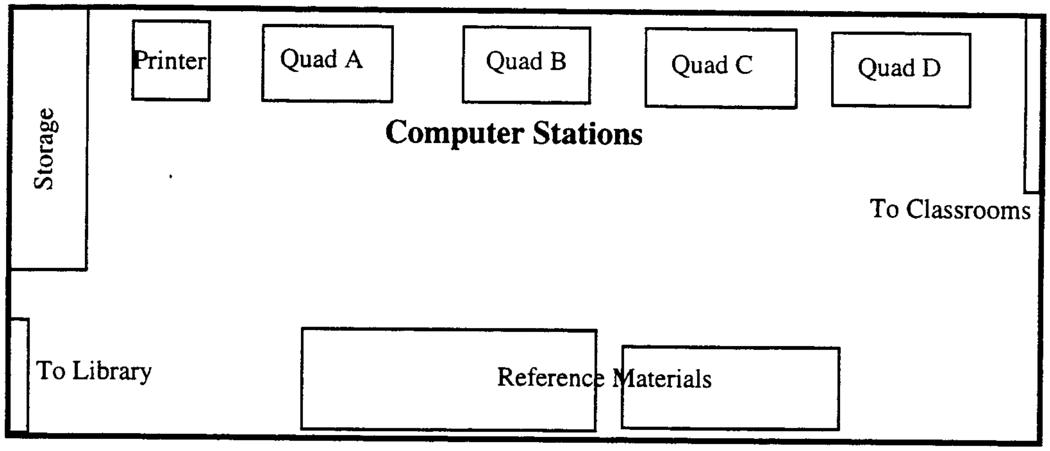


Classroom Setup

Juarez-Lincoln School is constructed in the loft-style typical of the schools built in this community in the 1970's. The classrooms are separated by modular walls with many interconnecting doorways and an average of two exits from each classroom. The sixth grade at Juarez-Lincoln was contained in three such classrooms, all interconnected physically to each other was well as to the area designated as the Computer Lab. During the planning stages of *Archaeotype*, one teacher decided that the team teaching approach necessary to implement *Archaeotype* would conflict with the model of *complex instruction* that she was carrying out with her students. Her class used *Archaeotype* in a self-contained classroom, while the other two classrooms adopted team teaching.

A fourth teacher, Bob Birdsell, was the Computer Lab teacher for the duration of this project. The Computer Lab was a small rectangular room (approximately 10' x 25') located off the library with a doorway leading to the sixth grade classrooms. One of the long walls was an accordion-type room divider. The Lab contained four desks with Macintosh LC computers daisy chained and attached to a laser printer. While *Archaeotype* is designed to be used with a fileserver, insufficient hardware resources forced the site to adopt a less optimal approach. One of the four student workstations was turned into a pseudo-fileserver through the use of System 7's file sharing capabilities. This slowed student access to the museum and library to a significant but acceptable degree. The initial setting up of the equipment was a difficult process for the teachers, with lack of prior experience and help exacerbated by hardware problems.

The four computers and printer were lined up against one wall of the Lab, with several tables along the other long wall which held the reference materials.



Ms. Campbell's and Ms. Quinn's students were combined and split into three different classroom groups with about 20 students in each group. These three classroom groups were rotated through a morning schedule, with the groups either in the Computer Lab using the *Archaeotype* software, in Ms. Campbell's room with language arts, or in Ms. Quinn's room for math.

Students attend Juarez-Lincoln from 8:30 a.m. - 3:00 p.m. (with a modified dismissal time of 1:30 p.m. on Thursdays). For the *Archaeotype* project, the time allotted for the three sections was modeled on the junior high schools in the community. The teachers felt that 55 minutes would allow the students time to process what they would be doing. The schedule for the Computer Lab, 4 days a week (Monday through Thursday), follows.

Archaeotype Schedule		
8:45	9:40	Group B
9:40	9:45	Passing
9:45	10:15	Group C
10:15	10:35	Recess
10:35	11:10	Group C
11:10	11:15	Passing
11:15	12:10	Group A
12:10	12:15	Passing

During passing times the students gathered their materials, lined up and proceeded to their next classroom area (all on command and as a group).

Team Taught Classrooms

Within Ms. Campbell's and Ms. Quinn's combined classes, students were able to choose one other student that they wanted to work with. They were then assigned to either Group learning groups. English proficiency was a factor considered by the teachers for placement. An important factor in determining the size of the groups was the number of computers available. Since the Computer Lab consisted of four computers, one for each quadrant in the *Archaeotype* software program, each of the three groups was further divided into four teams with the result being 4 to 5 students per cooperative learning team.

The students were assigned jobs with specific tasks and responsibilities to perform as members of their team:

Archaeotype Group Jobs

Recorder: Served as the historian for the group; responsible for group notebook, kept all papers together.

Leader: Made sure things got done; in charge of the group's presentation; speaker for the group.

Controller: Was accountable for watching and controlling the noise level of the group as they were working.

Monitor: Responsible for group involvement in the project; verified fair allocation of time on computer.

Materials: Responsible for group's reference materials; discovered other resource materials.

Self-Contained Classroom

Ms. Shane's classroom was divided into four groups (one for each quad). This resulted in teams of approximately 8 students. They went on-line using the *Archaeotype* software program once a week for 1 hour. The rest of the class (three other groups) were involved in other activities. For example, one group might be completing a worksheet, while another did artwork and the third group practiced measuring. At the end of their activity time, students came together as a classroom group to share the day's accomplishments. The students who worked with *Archaeotype* described their artifacts to the group.

What distinguished this self-contained approach and the team-teaching approach were the amount of time spent with the *Archaeotype* software, the size of the groups, and the interaction between students from different classrooms. Materials and activities for the two groups did intersect at times, but at most times the self-contained class operated independently.

Materials

The reference materials initially available to the students (and the teachers, for that matter) were very limited. Books were brought in from homes and public libraries to augment what the school already had. By the fourth week of the program, there were approximately

40 reference books on the table in the Computer Lab. This reference library changed somewhat daily as the teachers or the students added material to it, or individual books moved into the classrooms temporarily. The District Media Center supplied a kit titled *A House of Ancient Greece* consisting of 2 books, 2 filmstrips, a map, floor plans, sketches, a coin, and a pottery shard.

One of the more popular books was part of *The Usborne Illustrated World History* series titled *The Greeks*. Another reference book which was liked for ease of reading was Time-Life's *The Ancient Greeks*. *Eye Witness on Ancient Greece* was also a well-used reference book. Among the many other sources used were *Silver Burdett Picture Histories Life in Ancient Greece*, The Ancient World series *The Greeks*, and *See Inside An Ancient Greek Town*.

Activities

The implementation of *Archaeotype* at Juarez-Lincoln evolved continuously during the project, with modifications made as necessary by the teachers. Activities were introduced at various stages in the project to supplement the information provided by the *Archaeotype* software program. Some of these activities were group-oriented, while others required individual student work.

A typical lab period might go as follows: The students entered the Computer Lab and sat at their assigned quadrant computers. Mr. Birdsell brought the attention of the group together and provided a brief explanation of what they were to do that day. Their task might be simply continuing to dig and enter information on artifacts, reading an information sheet, completing a worksheet, or writing definitions of words. Mr. Birdsell then checked for group understanding, and after being assured that someone in each group understood what was to happen that day, the students were released to work on their own.

Students were responsible for maintaining *Archaeotype* Folders. The Recorder kept all the information for the group in a folder and kept possession of it (even overnight). All students were expected to record information, however, such as descriptions of what they found, copies of the printout of the artifacts, worksheet assignments, and reference material. The appearance and material contained in the Recorder's notebooks, as well as the individual students' notebooks, were of varied complexity and organization.

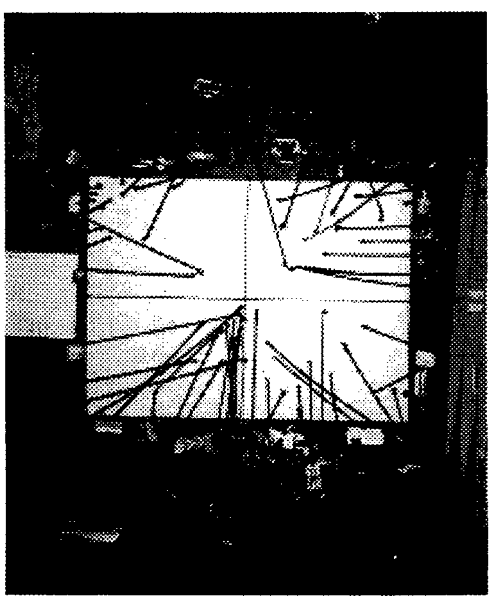
As noted above, the reference materials were minimal and the teachers found it necessary to provide information to the students directly through information worksheets with titles such as *The Trojan War*, *How We Know About the Greeks*, and *Ancient Olympic Games*.

One information source available in the Computer Lab was the Franklin Language Master. The students were able to use this electronic dictionary for pronunciation and definitions. Several students voiced the opinion that the "spelling machines" were fun and valuable; "It really helps", one student reported.

As a preparation activity before beginning *Archaeotype*, the students designed pots and/or vases using black crayon etches. This art activity strengthened understanding of symmetry and geometric forms, and the pottery associated with the ancient Greek culture. This project was done at the beginning of February, and is a good example of the efforts made by the Juarez-Lincoln teachers to integrate the instruction of *Archaeotype* with other areas of their curriculum. Later, the students extended this activity a step further by making vases and pots out of clay.

The teachers made various attempts to illustrate for the students real life examples of what they were doing in the dig. They discussed archaeological digs and dig sites. They attempted to find an actual dig site in their area, or to set one up on their own, but this proved unsuccessful. They did, however, use a piece of an artificial steel leg to illustrate the process one goes through when uncovering an unknown object. These lessons, not components of the *Archaeotype* software, were introduced by the teachers as the result of both intensive planning and spur of the moment ideas. The students enjoyed the artificial leg lesson and rated it verbally as "super".

On the wall of the Computer Lab was a poster titled *Archaeotype Write Up*. This was supplied to the students to aid them in their information gathering upon uncovering an artifact. Students were responsible for writing several paragraphs about each artifact they dug up. The *Archaeotype Write Up* provided prompts for the Physical Description: What does it look like?, What is it made of?, How large is it?, How much does it weigh? – and Thoughts and Ideas: Why is it here?, Where did it come from?, How old is it?, Have you found something like this before?, What do you think it is? On the walls of the classrooms was a piece of plain graph paper about 3 by 4 feet . These were Dig Site Graphs, one for each of the three groups. The Dig Site Graph was divided into four quadrants, replicating the *Archaeotype* dig site.



The students, as part of their learning group, placed printout copies of their artifacts on the wall and used yarn to link the picture of the artifact to the location of the object in the dig site.

Once when they did not have the use of the computers for the day, the teachers quickly devised a worksheet titled *Archaeotype Dig Worksheet.* On it the students were to fill in the columns with information they had begun to gather on their artifacts. The columns were headed by Object, Purpose of the Object, Materials, Time Period, Origin, and Connections/ Similarities to Other Objects.

The activities and methods used by the teachers were many and varied. In addition to those already discussed, there were various math skills which were taught by Ms. Quinn, all revolving around the Ancient Greek/*Archaeotype* theme. They displayed large timelines across all the rooms where dates of significant events were placed. Students were also involved in writing persuasive speeches and obituaries with a Greek theme. They studied *The Odyssey* and designed posters dealing with Greek myths. On several days they cooked food appropriate to the theme, including ambrosia and Greek salad.

During the last week of *Archaeotype* all of the students had to develop a "Greece Project". The final product could be written, drawn or constructed. Requirements for the project were purposely left vague in order to promote creativity. The students at Juarez-Lincoln, as pointed out by one teacher, are very limited in their ability to provide and use materials from home. This presented a challenge which was overcome by many of the students in some very creative ways. For example, one student used a tinfoil roasting pan to devise a helmet. Other final projects included coins, cartoons, maps, clay columns, and weapons.

Discussion Groups - Quad Shares and Site Shares

During a debriefing meeting held the third week of the project, the teachers discussed having times when the students could share information about their findings with the other students. They decided to have Site Shares (groups sharing information within their own site —A, B, or C), and Quad Shares (teams exploring the same quad would share information— A, B, C or D). These group shares were scheduled for 40 minutes near the end of the *Archaeotype* time frame for the day.

The flow of events across the *Archeotype* trial at Juarez-Lincoln can be grasped at a glance, and particular incidents can be contextualized, by reference to the calendar which appears on the following page.

Archaeotype Calendar

	Mon	Tues	Wed	Thurs	Fri
February	TT Week 1				
	TT Week 2				
	TT Week 3 SC Week 1			Visit by evaluators	
	TT Week 4 SC Week 2			Site Share	
March	TT Week 5 SC Week 3				
	TT Week 6 SC Week 4			Quad Share	
	TT Week 7 SC Week 5		Neil from Dalton	*Imagine* filming	
	TT Week 8			Final Site Share	

The first discussion group was held during the fourth week of *Archaeotype*. It was a Site Share, with essentially the same group of students who would be in the Computer Lab at the same time getting together in one of the three classrooms. The three teachers facilitated a group discussion regarding the artifacts that students had found.

Initially, different teams seemed not to be listening to the other teams but instead appeared to be working on their own presentation. Questions for the students after they presented an artifact seemed to focus on "How much does it weigh?, How big is it?" The teachers coached the students into thinking about other factors involved with the artifacts, rather than simply the data which they had to record when entering an artifact in the *Archaeotype* museum.

Discussion Groups were scheduled for every Thursday during the last weeks of *Archaeotype*. Teachers handled different groups each week. The first Quad Share was held during the sixth week. During the Quad Share, all classes came together (including Ms. Shane's) and were divided into groups based on their exploring the same quad in a dig site. These groups varied in their method and content of discussion depending on the teacher.

The final discussion group was a Site Share held at the end of the eighth week. The students were told beforehand in lab class to think about where the site is, where they think the artifacts came from, and so on. One of the final Site Shares was unfortunately hampered by the loss of the door to one of the classrooms due to vandalism. This made for a significantly noisier atmosphere than usual, especially when several other grades began their lunch period directly beyond the missing door.

With the final Site Share and Greece Projects, the *Archaeotype* trial ended at Juarez-Lincoln and the school closed for a three-week break.

Method

This evaluation was conducted with a combination of qualitative and quantitative methods. A great deal was learned through observation and interviews with the participants. Additional insights came from the analysis of an affective instrument, concept maps, and data collected by *Archaeotype* itself.

Observations

One or both of the evaluators visited the school a total of nine times beginning at the end of the third week of the project for a total of 34 person-hours of observation. During these times, activities of the students and teachers were videotaped on occasion for later analysis. Written and audio notes were taken as well.

Interviews

Interviews were done informally throughout all observation periods. In addition to this discussion time with students and teachers, more formal interviews were obtained from four students and all of the teachers involved in the program.

Student Interviews

When observing the students in the lab setting, the evaluator would ask what they were learning about, to relate what they were doing, what part they liked the best and least, etc. In addition to these informal interviews, some students were asked what they thought about the cooperative learning groups, what they were contributing to the project, what they thought about on-line and off-line resources, what they learned or found interesting or valuable. Students were asked to relate their overall feelings and opinion about the *Archaeotype* project. They were asked how they would compare the software program to textbook Social Studies.

Teacher Interviews During the Project

The interviews were open-ended and informal. The intent was to ascertain how teachers implemented the project, how they viewed the program, and what they saw as its strengths and weaknesses. They were encouraged to offer suggestions for changes and additions to the program, to relate what they would do differently or the same. Teachers were asked to compare the *Archaeotype* project to teaching from a Social Studies textbook. They were questioned about the materials and resources they had and wished they had. Each of the teachers was asked about their strategy for evaluating and grading the student's involvement in the project.

Follow-up Interviews

The teachers at Juarez-Lincoln were provided a copy of a draft of this report and asked to provide feedback on specific findings and inferences made. The teachers' input is reflected in this final report.

Quantitative Data Gathering and Analysis

Affect Ratings

How learners feel about instruction is an important aspect of any evaluation. Instructional units like *Archaeotype* that are carried out over several weeks are likely to inspire an affective response that changes over time. To measure the changes in affect through the course of the project, a simple instrument was developed. The form was given to students during Week 4 of the project. Students were asked to remember how they felt about *Archaeotype* during each of the first three weeks and to put an X in the grid location which represented their feelings. The grid was deliberately designed to resemble the map of the dig site, and students put their X in the center of a given space, not at the intersection of two lines. After Week 4, students filled out the instrument during each of the remaining four weeks.

The instrument was intended to measure three variables: Learner Interest, Perceived Clarity, and Perceived Amount of Learning. For each variable, a number was assigned to represent relative values (from 1-5, with 5 highest) for each level.

Student responses to this instrument were tallied and analyzed with the StatView 4.0 software package. Responses were also compared between LEP and Non-LEP students, between the team taught and self-contained classrooms, and between boys and girls.

Museum Analysis

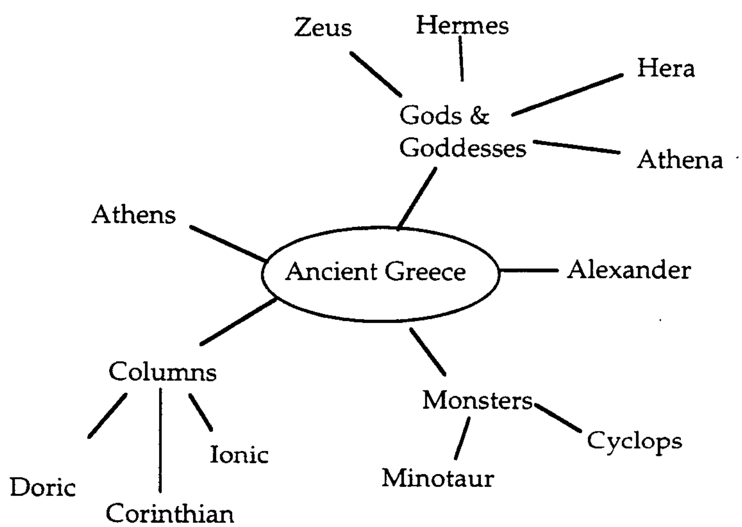
One major step in the process of using *Archaeotype* is to record information about artifacts found in the simulated Museum. The software automatically records the date on which the artifact was first entered into the museum. Three times during the conduct of *Archaeotype*, copies of the Museum files were made for later analysis. This allowed us to look for instances in which the description of an artifact was changed after its initial entry, ideally reflecting a deeper understanding of the artifact as the context was further explored.

For each artifact found, the number of words in the description was entered, along with the date of its entry into the museum (which might be the same or different than the date of its discovery). Each description was also analyzed in terms of the amount of information it contained which went beyond retelling the weight and other characteristics of the object. This variable reflected the number of inferences made by the team as they studied the artifact.

The museum data were entered into StatView along with the assigned group and quad for each of the 16 student teams. The composition of each team was also quantified in terms of the number of LEP students in the group. The intent was to see if English language proficiency had an impact on the ability of a team to find and analyze artifacts.

Concept Map Analysis

Twelve weeks after the end of the *Archaeotype* project, students constructed a concept map about "Ancient Greece". Concept maps test for meaningful as opposed to rote learning. By showing linkages among concepts, students demonstrate an understanding of how a topic hangs together. In a concept map, students name important elements of a topic and draw lines to represent relationships between concepts. Students received instruction in how to create concept maps on oversized (11" x 17") sheets of paper. They were told to put the words "Ancient Greece" in a central ellipse, and to connect to it to other, related, concepts. They were encouraged to identify categories subsuming other concepts (Gods, or Wars) close to the center and link subconcepts to them.



In this example there are a total of 14 items. There are three concepts which subsume other concepts: columns, monsters, and gods and goddesses. These are called "item streams" in the literature, and are counted more heavily in scoring the map.

The maps were scored using criteria suggested by Novak and Gowin (1984). The number of items recalled and the number of hierarchical concepts included were added to the database in StatView. Comparisons were made between LEP and Non-LEP students, between team taught and self-contained classrooms, and between boys and girls.

Comparison Groups

The ideal for an evaluation such as this would be to have a comparison group at hand that was learning the same content through traditional means and which was equivalent to the Juarez-Lincoln students in every other way. Both groups would be given a pre-test before the project start and a post-test afterward.

Circumstances did not allow us to attain this ideal. The evaluators were called in during Week 3 of the project, so no baseline measurement was possible. Repeated attempts to gain access to similar schools in the district were unsuccessful.

So to what can these data be compared? There are two types of comparisons: historical and future. Historically, we asked Juarez-Lincoln teachers to compare the *Archaeotype* experience with the way they covered the same content a year ago without *Archaeotype.* While such recollections were flawed by the imperfections of human memory, they have the advantage of holding constant the school context and student population.

Comparisons can also be made historically with the Dalton School. Assuming that the museum files from previous *Archaeotype* implementations at Dalton have been retained, they can be analyzed retrospectively in the same way that the Juarez-Lincoln files were.

The other direction that comparisons can be made is with future groups at Dalton and elsewhere. Using the affect instrument and concept map techniques described here, the Juarez-Lincoln data can serve as a baseline to which other schools can be compared.

Findings

No matter how well designed or intended, most research studies are impacted by unexpected events. Two things happened during the conduct of this evaluation which could not have been predicted, and which are likely to have had an effect on the data.

During the second to last week of the program, a television crew came to Juarez-Lincoln to prepare a segment for the Apple TV series *Imagine*. Never before had this school been the focus of such attention. Cameras and floodlights went from room to room as students were interviewed and filmed for a period of three days. Even if *Archaeotype* were not an educationally sound program, it would have acquired an aura of importance in the minds of most participants under these conditions.

On March 27, the day after the *Archaeotype* project ended for the team taught classes at Juarez-Lincoln, a fifth grade student from the school was murdered while riding his bike in a wooded area lightly populated with transients. Shock and grief was felt by the entire community, and most palpably at the school itself.

This event affects the results of the present study in several ways. The time immediately after *Archaeotype* which might have been used for consolidating and building on the lessons learned was instead filled with memorials, meetings, psychological counseling, and the process of grieving and acceptance. This affected the data we got from the follow-up interviews with teachers. It also, no doubt, had some effect on what students were able to remember about ancient Greece as measured by the concept maps.

In the section that follows, quantitative results—those derived from statistical analysis —will be reported first. That will be followed by a summary of inferences made based on interviews and observations.

Quantitative Findings

Affective Changes Over Time

The attitude of students towards what they are learning changes constantly. Learners come to a topic with some level of prior interest, high or low. As a lesson progresses, learners can become engaged by a subject they had no interest in before, or they can tune out. Depending on the level of challenges met or failures perceived, they can feel triumphant or frustrated. These are all possible affective outcomes of any form of instruction.

For a project like *Archaeotype* which spans several weeks, one would expect to see shifts in affect over time. One would expect an initial level of confusion and perhaps frustration as the bugs were worked out in implementing the project, followed by a sort of honeymoon period in which things were perceived favorably. And after that, perhaps a lull period as the honeymoon ends and the end is not yet in sight.

Three variables were gauged weekly in this evaluation: Interest, Clarity, and Perceived Learning.

Interest

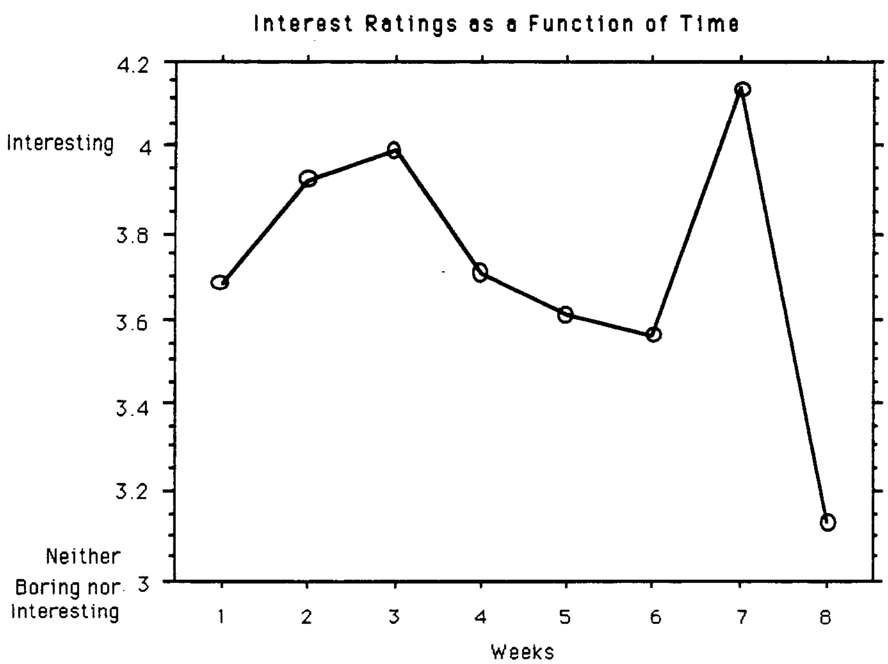
To analyze the dynamics of affect, each turning point in the graph was compared to the previous turning point with a 2-tailed t-test. To compensate for the increased possibility of a type 1 error (saying there was a difference when in fact there wasn't) the alpha level for the test was set at a conservative .01.

The graph of interest shows the predicted pattern at the beginning of the project. Initial interest was between "Interesting" and the neutral "Neither Boring nor Interesting". This may represent three contending factors: the prior interest level of the class in the topic of archaeology, the mildly aversive task of learning the mechanics of the program, and the excitement of novelty. The last factor is positive, while the first two might have been slightly negative. After a few weeks with *Archaeotype*, those who were not initially engaged in the topic may have been won over and the task had become familiar, so both sources of negative affect had been removed.

Interest peaked in Week 3 and then began a slow decline. The rise between Week 1 and Week 3 was not statistically significant, however. The decline in interest between Week 3 and Week 6 *was* significant ($t = 2.78$, $p = .0076$).

A sharp spike upward in Week 7 reversed this decline ($t = -3.189$, $p = .0024$). The drop between Week 7 and 8 was significant ($t = 4.467$, $p < .0001$). Interviews with the Juarez-Lincoln teachers indicate that the presence of the video crew was clearly responsible for the peak in interest in Week 7. The following week seemed anticlimactic to both students and teachers, as if (in one teacher's words) they were "beating a dead horse". Students who had not been interviewed on camera felt let down, and the fact that a three-week break began after Week 8 is also likely to have depressed the ratings of Interest.

If both speculations are true, then the true Interest curve, which would have occurred if the filming had not taken place, would likely to have continued the gentle decline shown in Weeks 4 to 6.

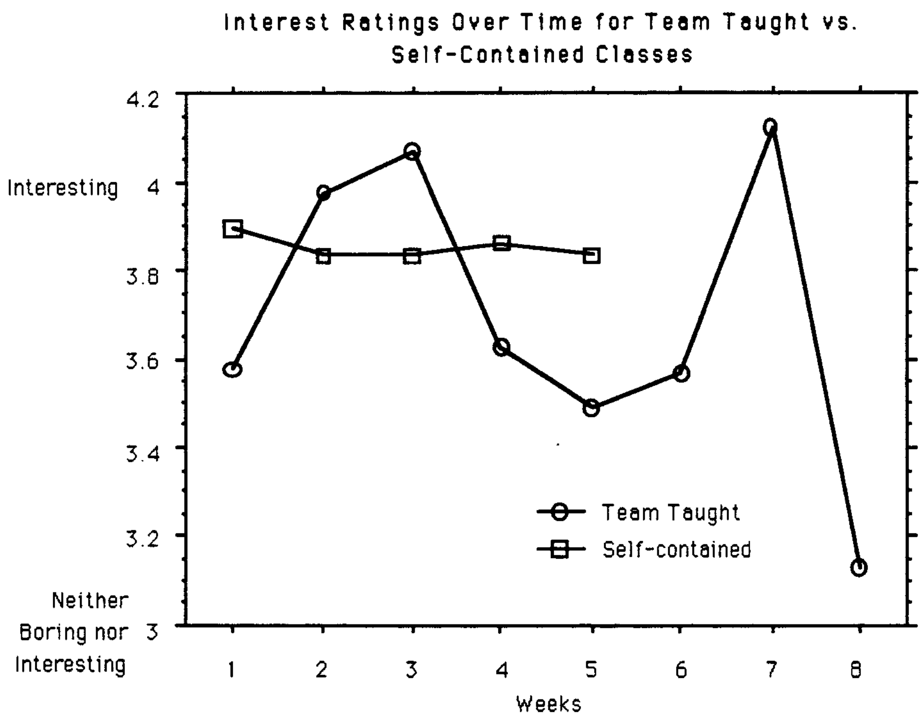


In general, the average Interest level expressed by students stayed between neutral and "Interesting". It should be noted that the Interest scale is a 5-point one, with 5 representing "Very Interesting". For each week of the project, the Interest ratings expressed by individual students ranged from 1 to 5. At any given point, some students were *very* interested, while others were *very* bored.

The interest ratings were examined for differences between LEP and Non-LEP students, and between boys and girls, and no statistically significant differences were found. In other words, the pattern of falling interest after Week 3, followed by a sharp rise in Week 7 and a drop in Week 8 was true for boys and girls and LEP and Non-LEP students on average.

When the Team Taught classes were compared to the Self-Contained class, an interesting fact emerged. The level of interest in the Self-Contained class changed very little over time.

When combined with the Team Taught class, this tended to water down the differences over time in the Team Taught classes. The pattern already described was more distinct when the Team Taught class is looked at separately.



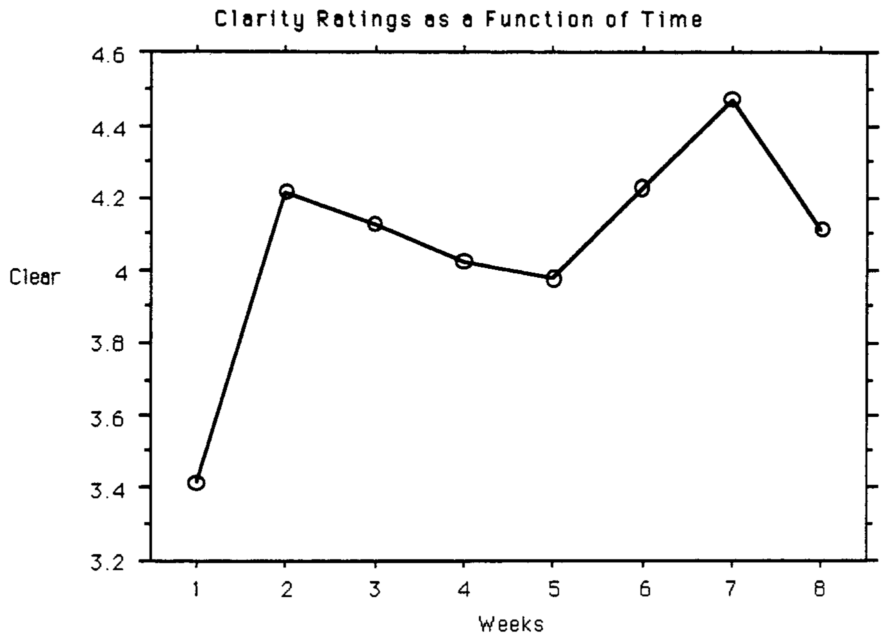
It should be noted that the Self-Contained class began to work with *Archaeotype* two weeks after the other class. Week 1 for the Self-Contained class occurred during Week 3 for the Team Taught class. To show how affect changed at comparable periods for each class, however, the times were analyzed from the point of view of each class, not by calendar time.

Clarity

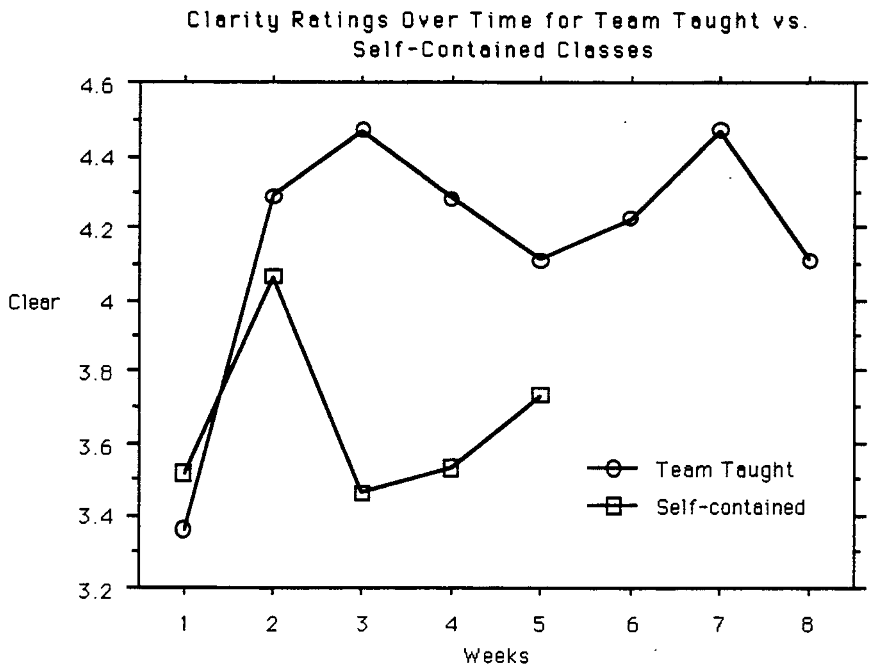
Students were asked to rate how clear the experience of *Archaeotype* was to them on the following scale: 1 = Very Confusing; 2 = Confusing; 3 = Neither Clear nor Confusing; 4 = Clear; and 5 = Very Clear. One would expect a low rating at the beginning of the project, given how different it was from any of their prior experience. One would also hope for a continuing increase in clarity as the project went on.

In fact, that is generally what students reported. From an initial state of lesser clarity in Week 1, ratings jumped significantly in Week 2 ($t = 6.04$, $p < .0001$). Clarity declined non-significantly to Week 5 and then rose again between Week 5 and Week 7 ($t = 2.901$, $p = .0055$).

This was followed by a slight drop in clarity in Week 8 which was not significant according to the stringent criteria we set ($t = 2.579$, $p = .0128$).

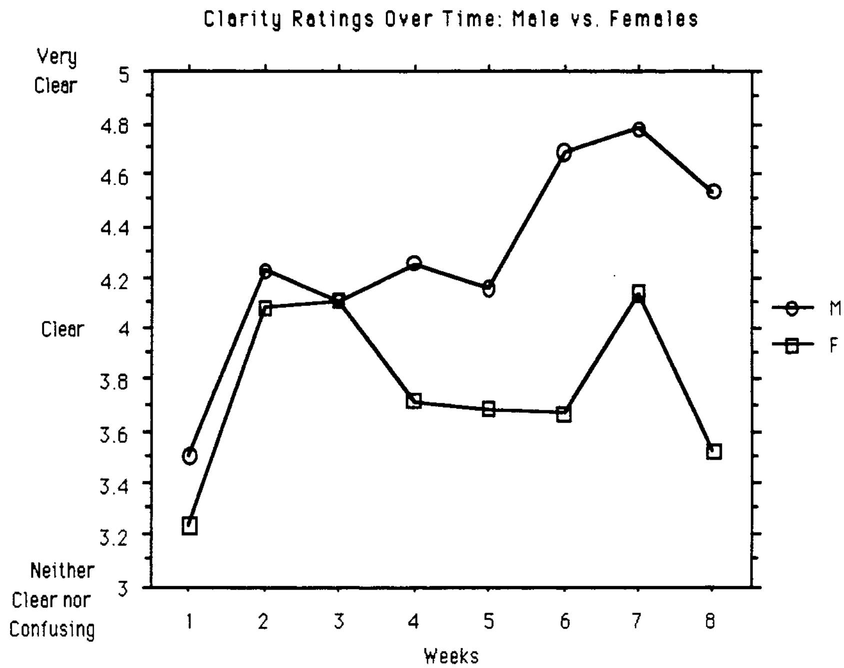


When LEP and Non-LEP students were compared, no significant differences in perceived Clarity were found. Comparing the Team Taught and Self-Contained classes showed differences in Weeks 3 and 4 that are difficult to interpret.



The differences in Clarity were significant in Week 3 ($t = 4.732$, $p < .0001$) and Week 4 ($t = 3.010$, $p = .0034$). However, if the graph of the Self-Contained class were to be moved to the right two weeks so that the two groups were lined up by simultaneity rather than by how far along they were in the project, the differences disappear. To the extent that children in the two groups were interacting with each other outside of class time, it could be argued that this latter comparison is more appropriate.

A more compelling difference emerged when boys and girls were compared.



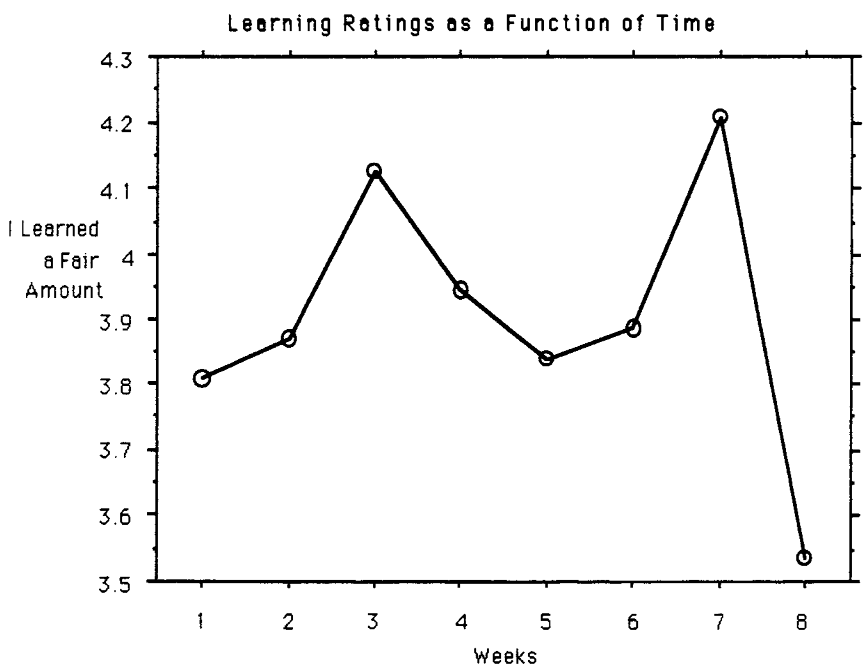
While both groups started out the project feeling equally clear about it, they diverged after Week 3. The difference becomes statistically significant in Week 6 ($t = 4.267$, $p = .0001$), and continues in Week 7 ($t = 2.737$, $p = .0088$) and Week 8 ($t = 3.359$, $p = .0016$). In Weeks 6 and 8 the difference in ratings was more than 1 full point. On a 5-point scale this seems not only statistically significant but educationally significant and worthy of further inquiry.

In our follow-up interviews the Juarez-Lincoln teachers were asked what there was about the tasks and activities in the latter weeks of *Archaeotype* that was more clear to boys than to girls. Is it possible that the project called upon some skill that boys have developed more fully at this age? The teachers were able to shed only a small ray of light on the question. Two of them speculated that the activity of making models of armor and weapons and columns, and having to ask parents for materials at home to create the models, was a more comfortable endeavor for boys than for girls. The size and duration of the discrepancy between boys and girls seems too great to be fully explained in this way, however, so the mystery remains. Future implementations of *Archaeotype* should be watched closely to see if the clarity gap recurs.

Learning

The third affective variable measured was the extent to which students felt they were learning new information and skills, which was scaled as follows: 1 = I Learned Nothing New; 2 = I Learned Very Little; 3 = I Learned a Little; 4 = I Learned a Fair Amount; and 5 = I Learned a Lot.

This variable followed the same pattern as the rating of Interest. It rose significantly from Week 1 to Week 3 ($t = 2.889, p = .0049$), drifted down non-significantly ($t = 2.050, p = .0436$), rose again from Week 5 to Week 7 ($t = -2.417, p = .0193$) and dropped precipitously in Week 8 ($t = 3.478, p = .001$).



There were no significant differences in this variable across classes, genders or language proficiency groups.

The initial rise in perceived learning seems to indicate that students felt that they learned more once they got the hang of the software and their roles. During the middle of the project one would expect the perceived amount of new learning to slump as students settle into the routine of finding and analyzing artifacts.

The rise in new learning in Week 7 was less easy to explain. Did the pace of the project accelerate in response to the presence of the media? Or does this represent the beginnings of deeper understanding as students began to cross-reference their findings?

Interviews with the Juarez-Lincoln teachers indicate that Week 7 was the last week of new learning, while Week 8 was a time of organizing findings and getting ready to report them to the other groups in the class. As with the Interest ratings, the presence of the Apple video crew intensified all perceptions and activities during Week 7 and gave a boost the ratings of Learning as well. The teachers viewed the depressed Week 8 rating as a combination of post-Apple letdown and of prevacation break distraction.

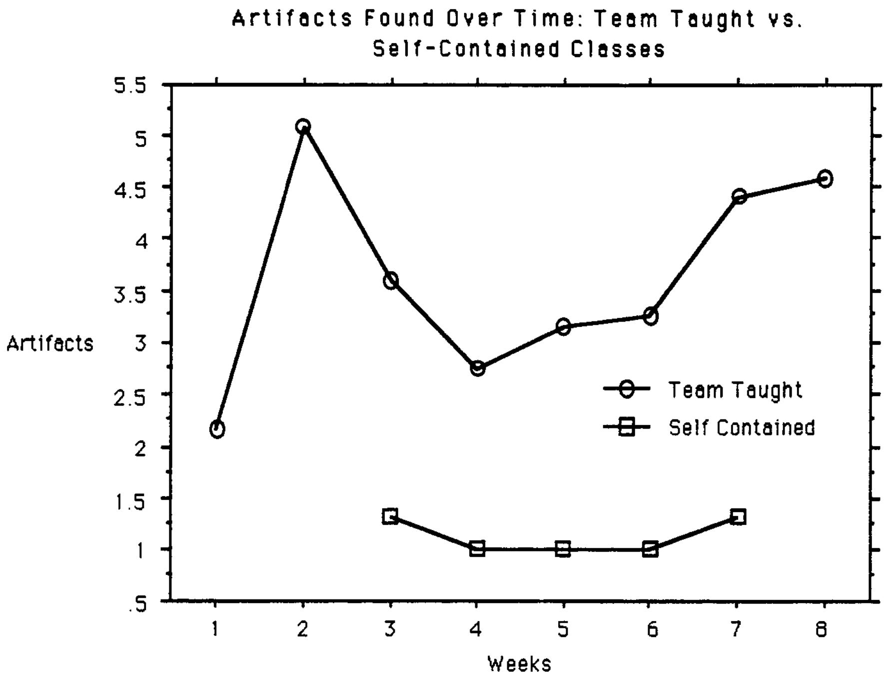
Museum Data Analysis

To study the rate at which students uncovered and analyzed items from the dig site, the museum files were copied from the fileserver three times during the project. The software automatically records the date on which the artifact was entered by students into the museum. The descriptions written by students about each artifact was analyzed across gender, class, and language proficiency subgroups.

Artifacts Found

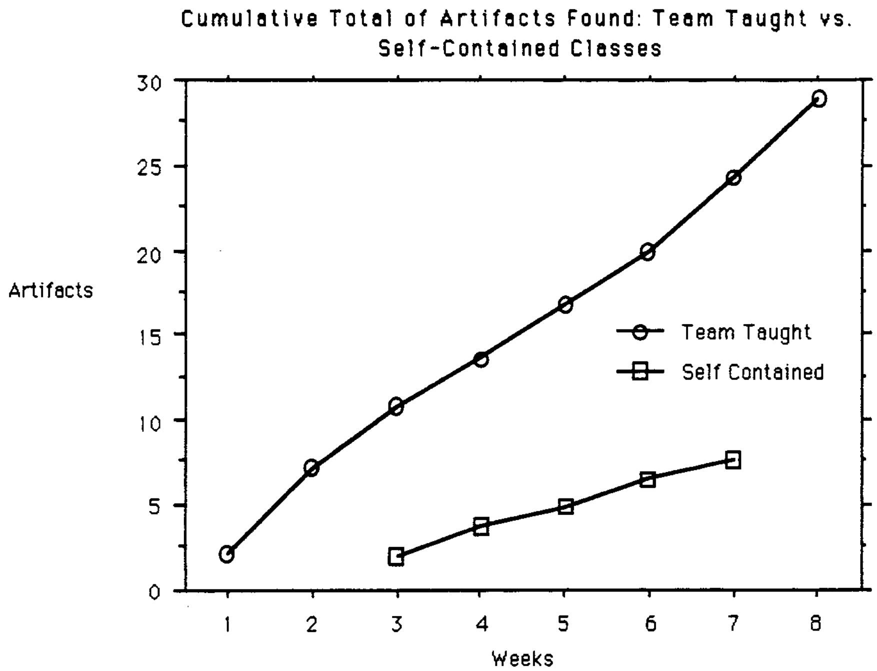
One way to analyze student progress through the simulation is simply to count the number of artifacts found each week. Because the Self-Contained class spent about one quarter of the time in *Archaeotype* that the other group did, their artifact-finding rate was significantly lower and so the two groups must be examined separately.

The four teams in the Self-Contained class found an average of one artifact per week during their one hour on the system. The Team Taught groups, on the other hand, averaged between three and five artifacts per week.

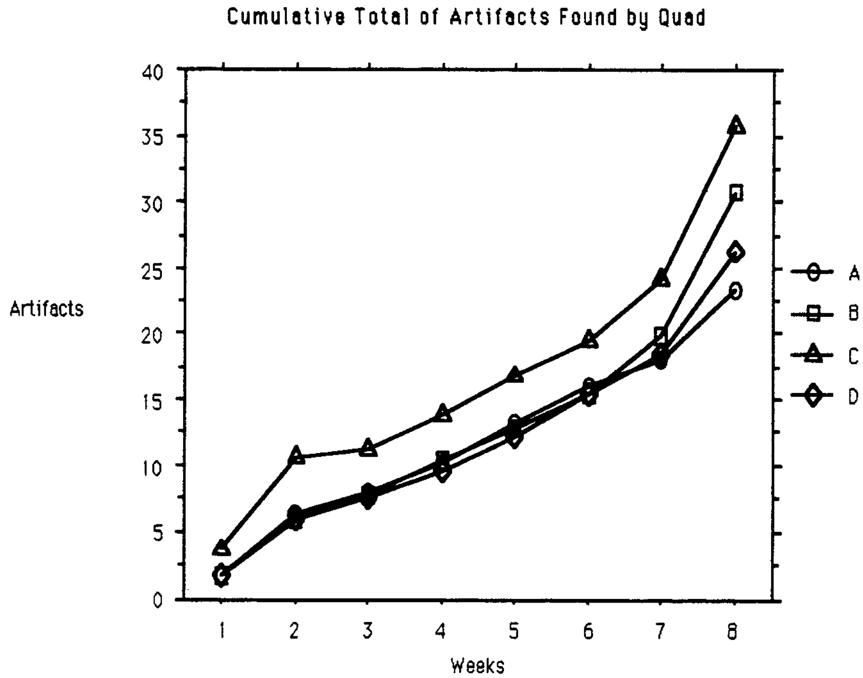


The rise between Week 1 and Week 2 is easily explained as a function of increasing familiarity with the software. The slump between Week 2 and 6 was harder to explain. Did the process of analyzing artifacts slow the teams down from finding new ones? Were students uncovering new artifacts but not recording them in the museum because of the work required by that recording process? According to Bob Birdsell, sometime around Week 2 the requirements for documenting their findings in the museum were made clearer and perhaps more stringent. Instead of quickly digging up artifacts at every turn, students had to spend their time weighing, measuring, and attempting to identify their finds. The midproject lull in artifact recording, then, simply reflects the fact that students spent their time analyzing more than in the first week.

Another way to look at the same data is to graph the cumulative total of artifacts found during the project. Again, these figures are team (not individual) averages and as such they represent the number of artifacts found in a single quadrant. By the end of the project the Self-Contained class groups had discovered (or at least recorded) less than a quarter of what there was to be found.



Did the rate of artifact discovery depend on which quadrant a team was exploring? The record shows few differences. Groups in Quad C found more artifacts during Weeks 1 and 2 which kept them ahead of the other quads for the duration of the project, even though they fell back to the same rate of discovery after Week 3. More was found in quads B and C by the end of the project than in quads A and D, raising the question of how evenly spread the artifacts are in the simulation.



Artifacts Found vs. Team Language Proficiency

Another issue to examine is the effect of having one or more students on a team with limited English proficiency. In practice, some teams operated in both English and Spanish, with bilingual students serving as the link between LEP students and English speakers and the teachers. Does this slow the discovery process down?

To answer this question, the number of LEP students on each of the 16 teams was counted. LEP students were distributed as follows:

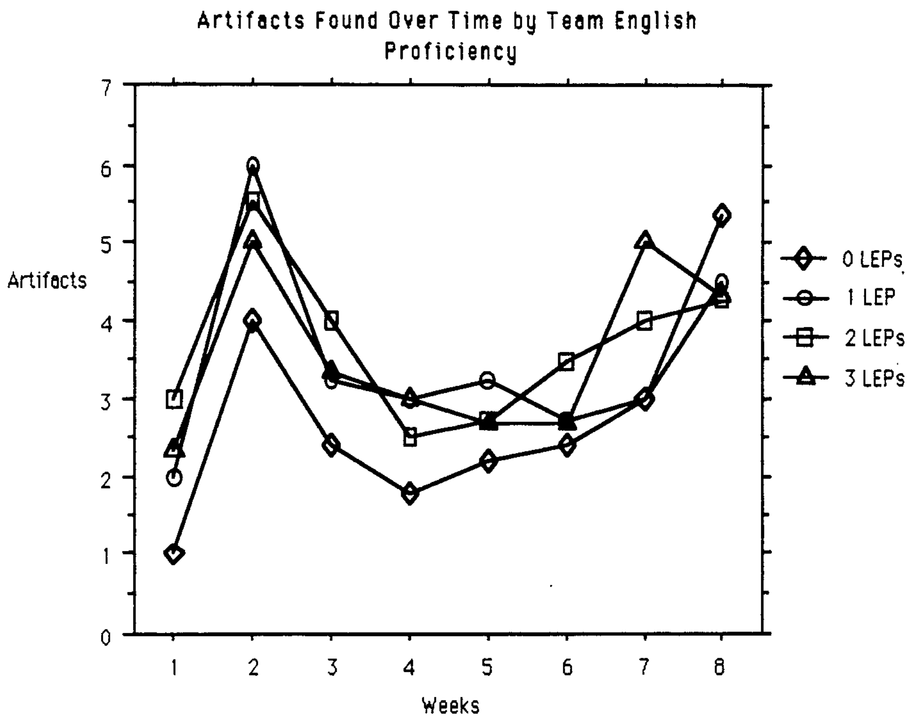
5 teams had 0 LEP students

4 teams had 1 LEP student

4 teams had 2 LEP students

3 teams had 3 LEP students

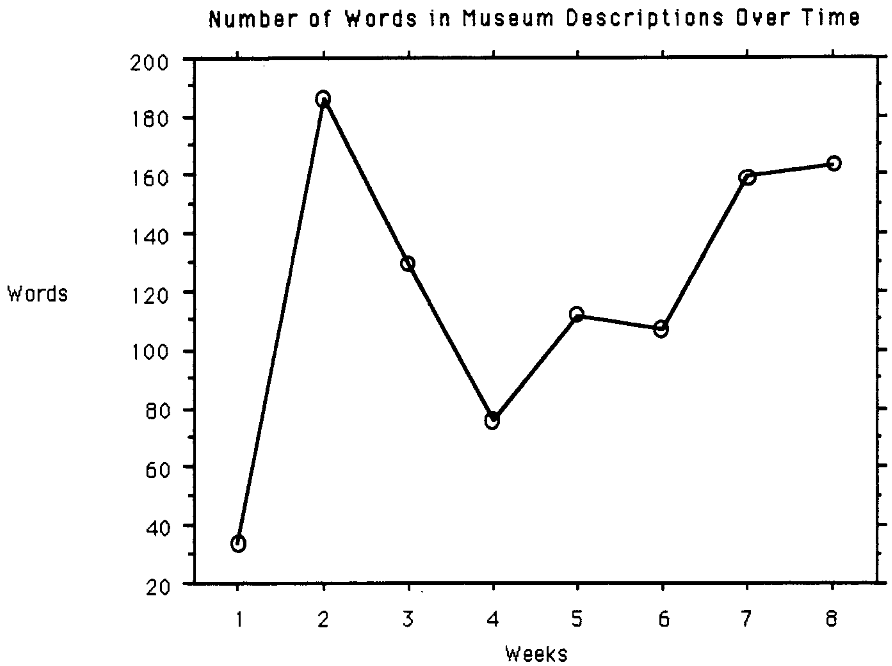
The number of artifacts found by each of these groups of teams was then examined.



While the numbers in a given week varied across groups, there was no consistent pattern related to the English proficiency level of the team. This means that *Archaeotype*, as implemented at Juarez-Lincoln, was not adversely impacted by the limited English proficiency of 29% of the students. Teams with 0 students identified as LEP did no better at analyzing artifacts than teams in which 3 out of 5 students were LEP.

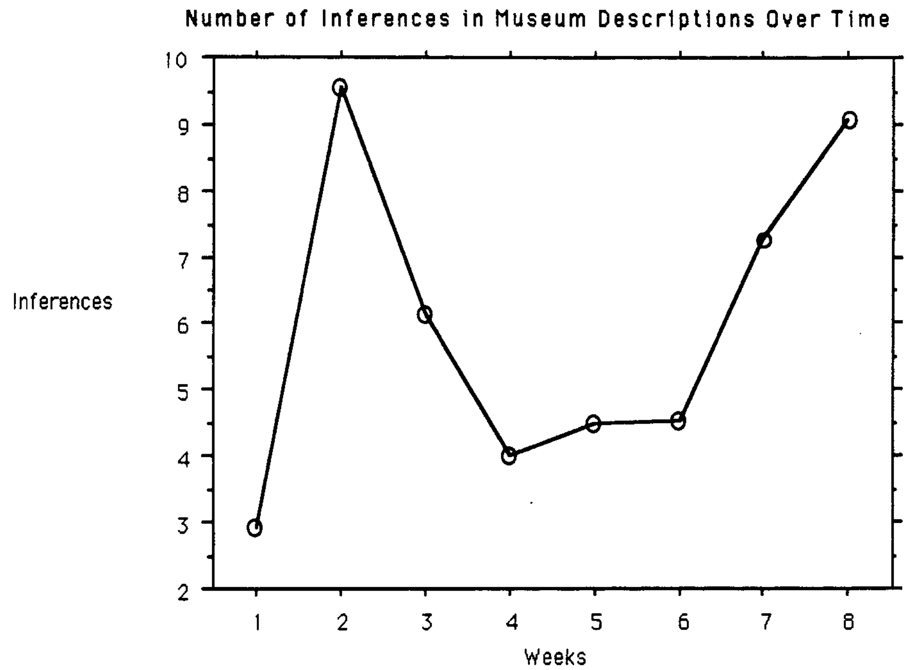
Words Added to Museum Descriptions

The next analysis of the museum data involved counting the words in the descriptions typed in for each artifact. By counting the words added to the museum each week, we were able to estimate the amount of new information generated by each team over time. The shape of the curve follows roughly the same pattern as the number of artifacts: a rise in Week 2 followed by a slump which turns around in the middle of the project.



Inferences in Museum Descriptions

The number of words in a description is only an approximation to the amount of new information being generated. To get closer to gauging information acquisition, the descriptions were analyzed for inferences. That is, the number of facts and guesses that went beyond the physical data reported in other fields in the museum was counted for each artifact. This variable followed the same pattern at the other two museum variables.

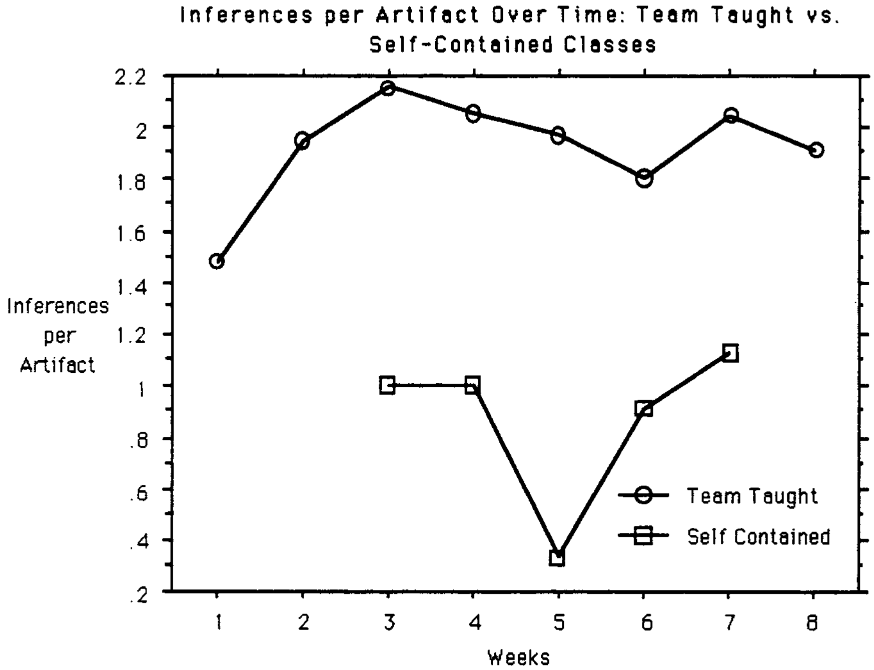


Inferences per Artifact

A final analysis of the museum data was conducted to determine if students showed growth in their ability to make inferences about the artifacts they found. Ideally one would expect that as they got deeper into the project and had more information at their disposal, they would have more to say about each new artifact. By the end of the project we would anticipate that students would be able to link an artifact with others already found, and to make educated guesses about its purpose and origin.

To explore this issue, the number of inferences made per artifact was calculated. This variable showed no significant increase through the project but instead remained essentially flat for the Team Taught class after Week 1.

The Self-Contained class made inferences at a lower rate which remained flat except for an unusual dip during their third week in the project.



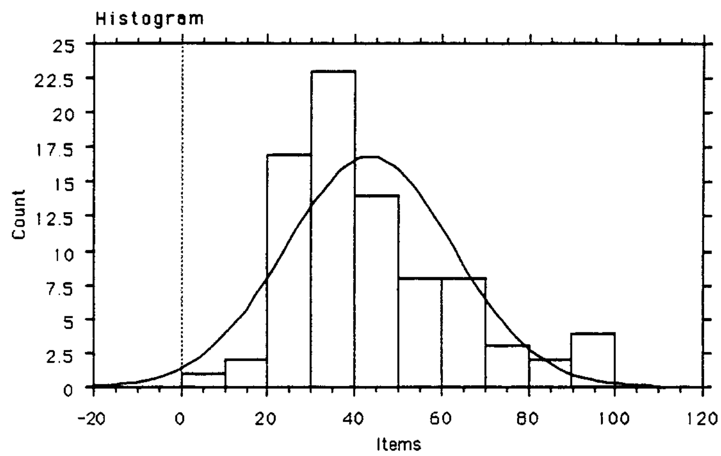
It is possible that the time taken by the mechanics of *Archaeotype* (uncovering an artifact, measuring it, etc.) constrained the students as they wrote their museum descriptions, and that perhaps they knew (and inferred) more than they had time to write. On the other hand, it may be that the cognitive load required to make such inferences was more than the students could handle, and that they looked at each new artifact somewhat in isolation.

In either case, there are indications that this aspect of the software (and/or its implementation) needs improvement.

Concept Map Analysis

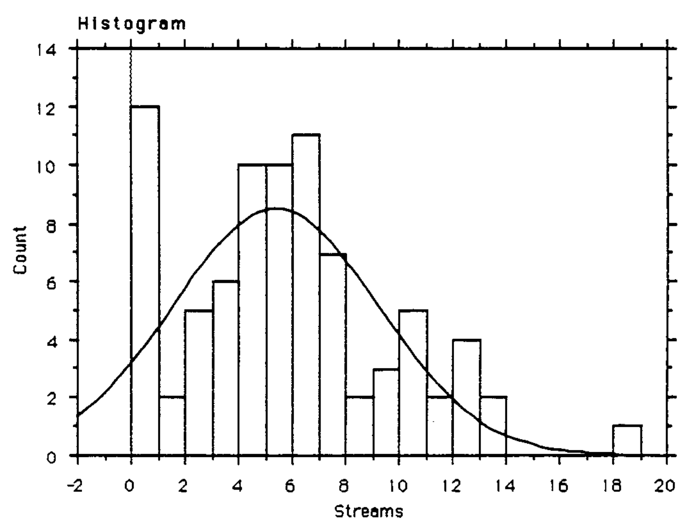
Concept Map Items

On June 10, 12 weeks after the end of the *Archaeotype* project, students were asked to construct a concept map about the central concept of "Ancient Greece". These maps were scored using criteria suggested by Novak and Gowin (1984). First, the total number of items on each map was calculated. The mean number of items was 43.4, with a standard deviation of 19.4. The number of items ranged from 9 to 99. The item scores were distributed more or less normally as follows:



Concept Map Item Streams

The concept maps were also evaluated for what Beyerbach (1986) calls "item streams", or what Novak & Gowin (1984) call hierarchies. For purposes of this study, an item stream was defined as a chain of two or more concepts subsumed by another concept. The number of item streams in the maps ranged from 0 to 18, with a mean of 5.4 and a standard deviation of 3.8. Item streams were distributed as below:



Item Streams Used by Students

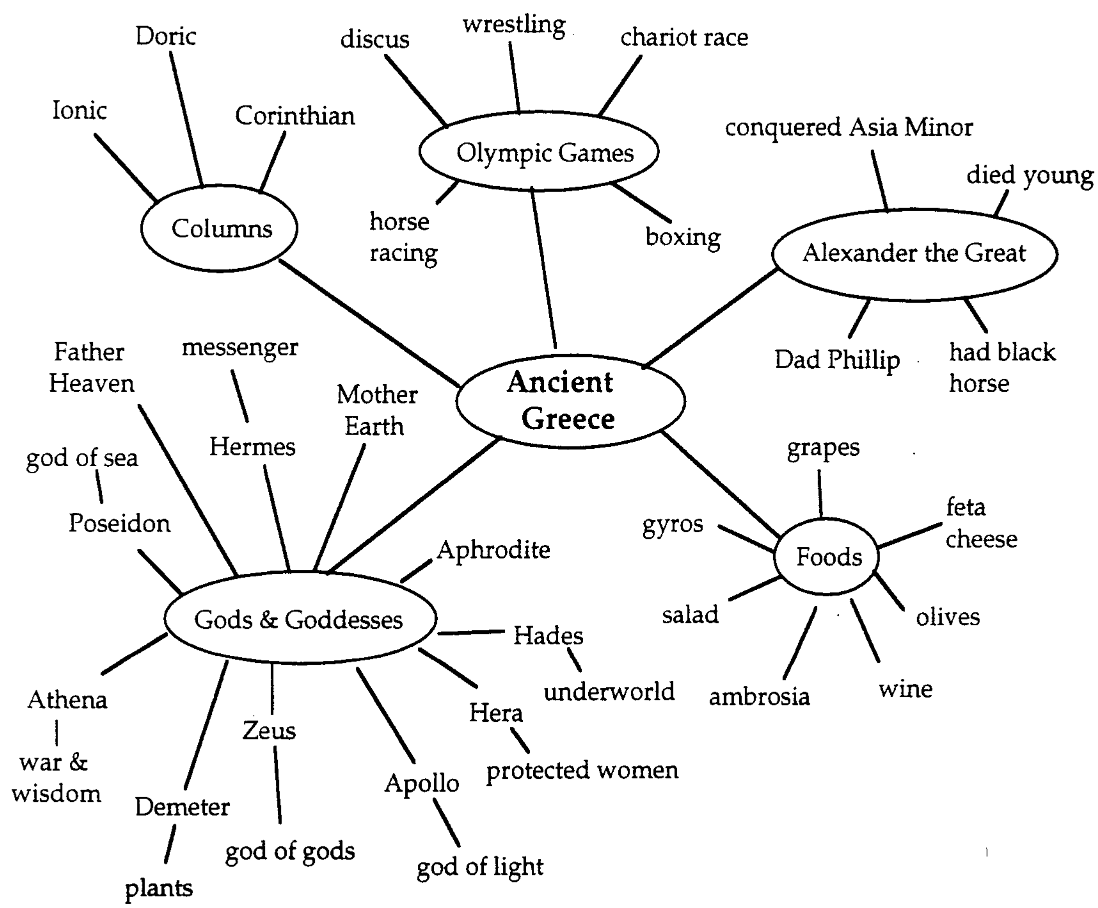
What concepts did students use to organize what they learned? There were clear distinctions between the Team Taught and Self-Contained classes. These variations reflect different emphasis given to aspects of Ancient Greece in the off-line activities in each class. The ten most commonly used categories in the two groups share only four topics in common: Gods & Goddesses, Foods, War, and Columns.

Team Class (N = 54)		**Self-Contained (N = 28)**	
41	Gods & Goddesses	23	Foods
24	Foods	17	Art
18	Olympic Games	17	Gods & Goddesses
16	Columns	10	Clothing
12	Alexander the Great	10	Money
12	Transportation	9	Religion
11	War	7	War
10	Armor	6	Myths
9	Government	6	People
8	Ages/Time Periods	4	Columns
8	Sparta	4	Monsters
7	Architecture	4	Music
7	Athens	4	Sports
7	People	4	Temples
7	Pottery	4	Theatre
7	Weapons	3	Architecture
4	Arts	3	Armor
4	Cities	3	Olympics
4	Stories	3	Statues
3	Hercules	3	Vases
3	Myths		

To convey a sense of what students learned from the *Archaeotype* project and retained twelve weeks later, two concept maps follow.

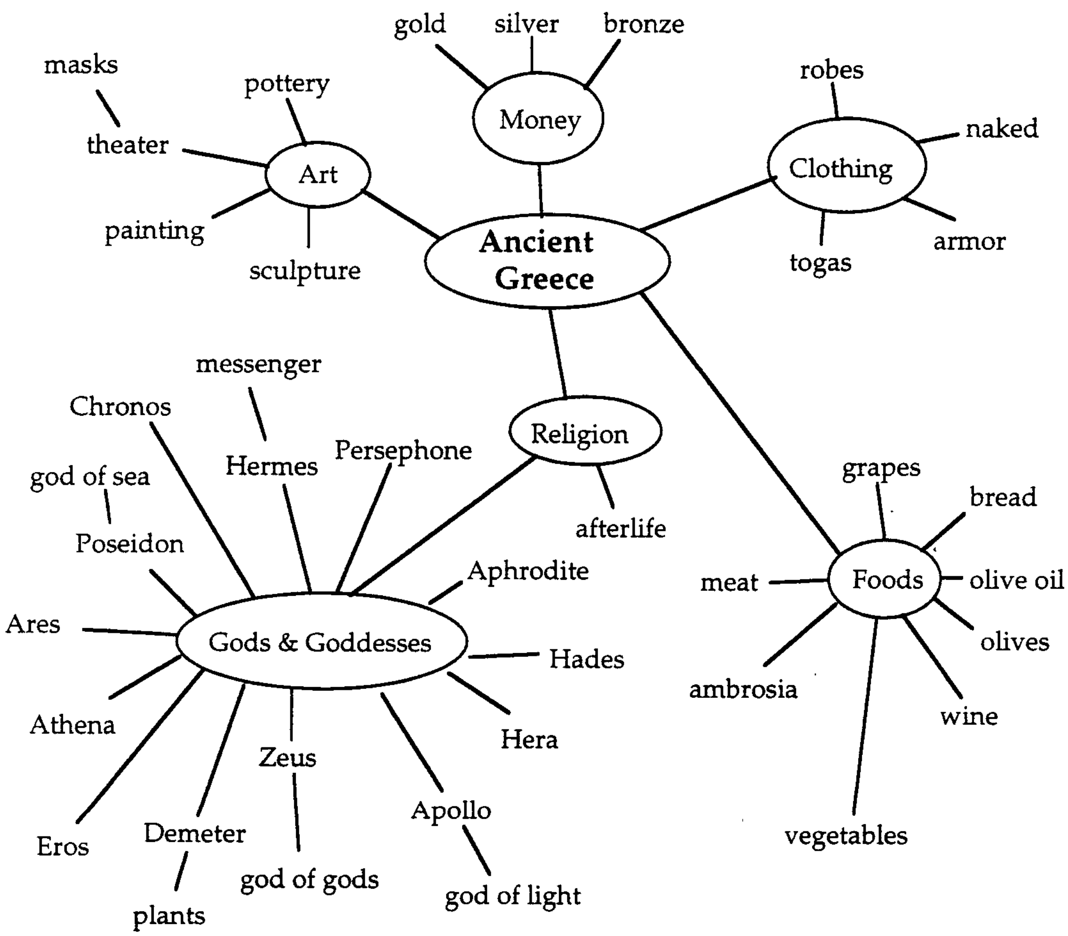
Typical Concept Map: Team Taught Class

This map shows the five most common item streams used by the students in the Team Taught classes, along with the items most commonly used within those streams.



Typical Concept Map: Self-Contained Class

The next map shows the five most common item streams used by the students in the Self-Contained class, along with the items most commonly used within those streams.



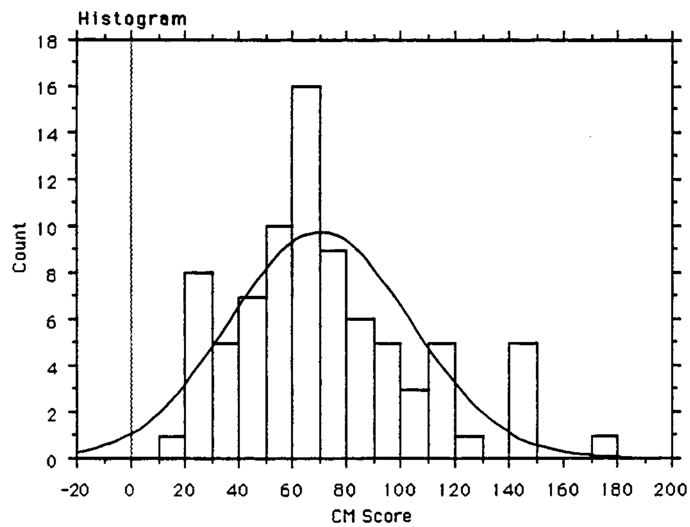
The differences in content maps between the two groups represent differences in emphasis that one would expect between any two classes operating independently. The students in the Self-Contained class had a very different experience than in the Team Taught class, and *Archaeotype* represented a much smaller part of that experience for them.

Concept Map Total Scores

While quantifying concept maps is an inexact science, it is possible to assign numbers to maps which reflect their completeness and complexity. As suggested by Novak & Gowin (1984), item streams were given more weight than individual concepts by a factor of five. That is, the total concept map score was defined as follows:

$$\text{Total Score} = \text{\# items} + 5(\text{\# item streams})$$

The total scores for concept maps ranged from 19 to 171 and had a mean of 70.4 and a standard deviation of 33.4. The distribution was approximately normal.



Total Concept Map scores were compared between LEP and non-LEP classes, Team Taught and Self-Contained classes, and boys and girls. There was a significant difference in scores between the LEP and Non-LEP students.

This difference was significant ($t = -2.959$, $p = .0041$) and was primarily due to differences in the item stream scores. LEP students used fewer subsuming concepts than Non-LEP students (Mean = 2.632 vs. 6.222) to organize their maps. This figure probably means that the LEP students retained less of the structure of what they learned in *Archaeotype*, though a part of their lowered score may also reflect a lack of understanding of the directions given orally on how to create the concept map.

Qualitative Findings

Students at Juarez-Lincoln work on *Archaeotype*

In the section that follows, general statements based on our observations and interviews are described and elaborated. Our initial draft of these findings was validated in our follow-up interviews with the Juarez-Lincoln teachers.

Students enjoyed working with computers.

The *Archaeotype* project holds special appeal for the students simply because it is on a computer. When asked what they liked most about the project, many students made reference to the fun of being able to use the computer. Students didn't appear to be hampered by any lack of computer experience. The program appeared to be generally user-friendly for this grade level.

Student motivation and involvement levels were high.

All of the teachers felt that the students were enthusiastic about the program. They perceived them as sticking to their research—continuing to look at the books from the lab table, getting books from other classrooms, hunting certain books and/or pictures down, even into the last week of the project. They perceived the students as being "turned on to history". During lab sessions that we observed, most students seemed to be on task a remarkably high percentage of the time.

The simulated uncovering of an artifact would be enhanced through a real life re-creation of an archaeological dig.

The students appeared to be interested in uncovering the dig site. It is interesting to note that several groups had their whole site dug up in the final weeks and were choosing the pieces they wanted then to explore. A leader of one of the groups stated near the beginning of the project that she liked to sift for artifacts the best, and everyone in her group agreed with her.

Students benefited from cooperative learning groups.

Students learned to function as a member of a team. They learned to cooperate and work with other groups, as well as their own group members. This teamwork was observed many times—students negotiating access to the museums and the printer; discussing what to name an artifact, how to research it; deciding what information to include in their museum notes. An example of the ability of the students to cooperate across group was an observed negotiation between different groups to access the museum—"We only need to go in to send it (a piece to the museum)", "Just a few seconds more and then you can have it", "Okay, thanks". The evaluator also observed during a different class and time a conversation among team members—"Let somebody else into the museum now", "But we need to put other things in", "Well, let someone else in, it's not fair".

LEP students benefited as members of cooperative learning groups; it helped to boost their self-esteem as they felt more a part of the team.

All of the teachers felt that the participation in a cooperative learning group was a good experience for the LEP students. The evaluator observed what appeared to be a fringe member of one group (a Spanish-speaking girl) bring to the computer station a reference book. The leader (another girl) said, "Oh, my God, she found the exact picture in the book. It's got a lot of things about Augustus. Look at this... Give me five." The LEP student smiled broadly, having contributed something worthwhile to her team.

The group size should ideally be 3 to 4 students. The overall consensus among teachers and students was that 3 to 4 students was the best number for a cooperative learning group. Problems were observed occurring in groups with more members than was comfortable. In a group of five, bickering back and forth was observed at least once. Students were arguing over where to go, what to uncover, and how to handle the mouse.

Teacher role changed to one of coach/facilitator.

The *Archaeotype* program was implemented as a student-centered, process-oriented project. The teacher "engages with the students as a peer" is the way one teacher put it. The role of the teacher changed from knowing all the right answers, to helping the students to come up with the answers. A teacher has to be comfortable with this role shift.

Students learn from each other and reinforce knowledge gained on their own or from the teacher.

There were many instances observed of students helping each other, teaching each other, reinforcing skills that they had attained through helping another student to gain the skill. Two boys were working on weighing an artifact. One of the boys weighed the artifact in grams, 2,812 G. His partner said to put it in a smaller weight, so "weigh it again". The boy with keyboard control put in the decimal point and said "That makes it KG" (2.812 KG). The other boy wasn't so sure and wanted to check it by weighing it again. They did, "See, I told you".

Students had the freedom to work independently of the teacher.

The teachers attempted to provide the students with an environment in which they could work fairly independently of the teacher. Students were given prompts to aid them in writing about their artifact. The Computer Lab teacher did not correct spelling, nor make attempts to help the students write their findings. The evaluator did not observe any instances of the students stopping to ask how to spell something or how to write down information. Students would enter words on their own into the electronic dictionary to get the pronunciation and definition, rather than ask the teacher. The evaluator observed students very willing to attempt spelling, etc., themselves. There were problems at times with the software program or the computer, or they had questions with what they had found. It was not that the students weren't comfortable interacting with the teacher, it was that they seemed very at ease with their ability to accomplish their work on their own as a team.

Grid mapping is an integral part of program.

In order for the students to get the "big picture", they must be able to represent the entire dig site in some way. Ideally, this reconstruction should follow along the manner employed by the teachers at Juarez-Lincoln. This would require the refinement of size specifications and capability of printing the artifacts to fit a large scale replica of the dig site. The use of the yarn as a place definer is too unwieldy, and weakens the impact of the replica. Despite this drawback, the grid maps did have an impact on the students' learning. During the final weeks of the project, students gathered around the Dig Site graphs—"Oh, look what they just found.", "We found that helmet." The evaluator observed a group of girls in the sixth week asking the teacher why all the quads but one encountered the same pieces of column.

Students could benefit from instruction in reporting skills and strategies for organizing data.

The students were responsible for maintaining a group notebook, as well as individual logs of their own. Observation of these notebooks showed an wide range of quality. Students had varying degrees of neatness, writing ability, artistic talent, etc. But overall, it was felt that all of the students could gain from direct instruction in strategies for organizing and compiling their data. Feedback on the frameworks they use individually would strengthen retention and enhance learning.

Facts and inferences made by the students can contain errors.

A good example of this is the group that came across a column that was too large to be measured in the usual manner. What could they do? They decided to estimate. The part of the artifact that they could see on screen measured 139 cm. This was a little more than half of the total object, but they estimated a final measurement of 140 cm. This was off by quite a bit since they still had a large piece to measure. No one thought to measure parts. Later in a group meeting they were asked how they got the size—"We estimated"; teacher says "good strategy". While it was a good strategy, the results they arrived at were erroneous.

Further development of on-line libraries is needed.

Teachers and students were asked their opinions of the on-line libraries included with the program. While the reading level was viewed as "a little too high" and that some of the writings could be shortened, most of their suggestions were for additions to the libraries. Many of them felt that there should be information on coins in the library. Armor and helmets appeared to be in excess. Sculptures in the library are limited to male nudes and all marble, no bronze. The transportation systems information could be helpful but is not necessarily conducive to the dig. The Architecture and Pottery library was felt to be good. More information could be provided about the wars, and summaries of the ages, time periods, and cultures would be helpful.

A group from quad A found the chest, Pandora's Box. Typical of most of the students, they were very interested in decoding the inscription. The alphabet on-line couldn't really help them since the inscription appeared to be in script. The students stuck with this unproductively for 8 minutes until it was time to leave for the day. The means of decoding script found in the dig site probably should be available on-line.

Resource materials that could supplement Archaeotype *instruction should be listed and categorized.*

One of the most frustrating aspects of the project for the students (and the teachers, for that matter) was the inability to find information on an artifact they were studying. One student stated they felt "mad" because they always wanted to find the information (preferably an exact picture of the artifact they uncovered). While some frustration is useful and realistic, a listing of suggested reference materials would be helpful. The availability of materials outside of the school site is very limited for these students. In fact, the materials located at the school itself are very limited, and certainly wouldn't compare with the library located at The Dalton School.

Several technology refinements of the software can be suggested.

Images should be in color, unless that slows the program down further. The ability to zoom in on objects and to flip and manipulate artifacts in numerous ways would also help. Some objects are difficult to uncover and place in museum (e.g., large statues), and this difficulty serves no apparent educational purpose. It would be useful if students were able to scan images from the research findings and put them into their individual notebooks.

Teachers and students were not as successful at achieving an understanding of the entire dig site in the culmination phase of the project.

The students did not appear to complete the process of going from the pieces (artifacts, research data, general statements) to the whole—the final model. How all the quadrants and artifacts were interrelated was a jump that most, if not all, of the students were unable to attain.

In interviews with the Juarez-Lincoln teachers, the reasons for this became clear: the goals at Juarez-Lincoln and at Dalton were different, partly by accident, and partly by design.

A document describing the overall objective of the simulation—that is, to put all the pieces together and develop a hypothesis about the whole dig site—was sent to Juarez-Lincoln in September of last year and filed away. By the time the simulation began, it had been forgotten. The implementation of *Archaeotype* at Juarez-Lincoln focused more on the process of discovery and hypothesis-generation about individual artifacts and less on the synthesis of all the discoveries together. Midway through the project when the assignment document surfaced, the teachers took note of it and tried to nudge students more in the direction of cross-artifact synthesis, but that never became the overriding goal.

The lack of a whole class, whole site "aha" then, should not be seen as a failure in the culminating phase of the project, because the teachers were striving for something more modest. In planning for next year's implementation of the project, the teachers seemed ready to take another look at the final goal and culminating activities. Without a deeper background in archaeology and the history of the ancient world, however, most teachers would find this final synthesis to be very challenging.

Summary and Recommendations

Overall, we would have to rate the Juarez-Lincoln trial of *Archaeotype* to be a success. Students felt generally positive about the experience and many were able to recall a reasonably well-organized body of concepts about the topic twelve weeks after the project ended. Teachers were successful in integrating *Archaeotype* across the curriculum, even though the *Archaeotype* package itself contained very little in the way of guidance or material toward that end.

That last fact can be re-stated another way: the success of *Archaeotype* at Juarez-Lincoln could be attributed as much to the quality of the teachers involved as to the quality of the software. This can probably be said for any successful educational technology... that at its worst it doesn't get in the way of good teachers, and at its best it invites the energy of teachers and allows them to do things they'd never dreamed of. *Archaeotype* seemed to bring out the best in these teachers.

This trial was not, of course, an accurate picture of how *Archaeotype* would fare as a widely disseminated product. Not all schools have teachers as dedicated as these, or a principal as supportive and effective as the one at Juarez-Lincoln. And not every school will have the benefit of visits and consultation with the designers from Dalton. If *Archaeotype* is to go beyond the trial stage, what more must be done?

1. Teacher support materials are the most critical missing piece. Teachers will need advice on how to set up the software, hardware, and facilities; how to configure themselves for team teaching and cooperative learning; what skills to teach or reinforce directly before the simulation begins (e.g., teamwork, metric measurement, reference skills); and ideas for lessons and activities to build around the simulation. Teachers

will need particular support in leading the class to build hypotheses about the dig site.

2. Reference materials are another necessity. A well-tested list of core references and optional extra references needs to be developed. Ideally materials in Spanish can be located and added to the list. Some guidance on how many copies of each reference would be needed for a given class size would be helpful. It may make sense, in fact, to package *Archaeotype* with a set of core references rather then leaving the purchase of books as an additional administrative chore.

3. Tie-ins to existing textbooks should be developed. When asked, the teachers did not feel that *Archaeotype* could replace a textbook, but that it provided strong motivation for students to use textbooks proactively.

Our final recommendation comes not so much from our observations at Juarez-Lincoln, as from our own experience as educational software designers. While the Week 7 videotaping makes it difficult to gauge the true motivational pattern experienced by *Archaeotype* students over time, it does appear that there was a general drift downward in interest after the third week. Can something be done within the software to counter this?

4. We recommend that building some form of conflict or surprise into the simulation be considered. While these may already exist in the form of artifacts from disparate times or cultures being found side by side, there was little evidence that this resulted in the kind of conceptual conflict that leads to greater curiosity. Without sacrificing the integrity of the simulation, can another source of mystery, paradox, competition, or tension be developed? If so, it should be deliberately designed to come into play sometime after the fourth week of the simulation.

As an almost complete work in progress, *Archaeotype* shows very great promise. We hope that the development of support materials and refinements in the software will continue, and that more schools and more children will soon be able to learn from this innovative package.

References

Beyerbach, B. A. (1986). *Concept mapping in assessing prospective teachers' concept development.* ERIC Document Reproduction Service No. ED 291 800.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn.* Cambridge: Cambridge University Press.

NSF Grant Application—*Archaeotype 3.0*: Helping Students Master Core Subjects Through an Advanced Computer Simulation

One: Objective

To develop *Archaeotype 3.0*, a new version of an advanced computer simulation introducing students to the study of history and geography, along with other interdisciplinary possibilities such as math and ecology; and to institute a program apprenticing public and private school teachers in New York City in its use in culturally and economically diverse school settings.

Through *Archaeotype 1.0*, on Ancient Greece, and *Archaeotype 2.0*, on Assyria, sixth-grade students collaboratively excavate simulated archaeological sites and construct historical interpretations of the cultures evidenced by the art and artifacts they uncover. These existing versions of the program have been successful prototypes. The project we propose will create *Archaeotype 3.0*, a new site on ancient Egypt and a production version of the program that will be suitable for testing in diverse settings and will lead to its general distribution. As an effort to develop and advance a significant educational innovation, the project will include the following features:

(a) It will further develop an innovative software program created through a collaboration of key teachers at the Dalton School, working through its New Laboratory for Teaching and Learning; scholars and educators at Columbia University, working through the Institute for Learning Technologies at Teachers College; specialists in the Educational and Curatorial Departments of The Brooklyn Museum; and programmers, graphic artists, and network developers from these institutions.

(b) It will enable the New Laboratory for Teaching and Learning at the Dalton School to introduce *Archaeotype* in public schools throughout the boroughs of New York City in order to test the program in a variety of school settings.

(c) It will enable the Institute for Learning Technologies at Teachers College to expand its program for developing the capacity of teachers to use programs such as *Archaeotype* as renewal agents in their schools.

(d) It will extend ongoing efforts to develop and apply novel assessment strategies in classrooms using *Archaeotype*, in which learning emerges through cooperative activities in which students interpret primary artifacts of our culture.

(e) It will make important artistic and archaeological artifacts from The Brooklyn Museum available to a wide audience that would not otherwise have access to them.

(f) It will lead to a version of *Archaeotype* that can be adopted generally in schools throughout the nation, engaging a generation of children in a deeper, more vital study of the ancient world.

Two: Need

Archaeotype is a collaborative interactive simulation created to meet evident needs of the classroom. A class of students, divided into four teams, each working at one of four networked multimedia computers, excavate a complex archaeological site and cooperate over a period of ten to fourteen weeks to interpret the culture evidenced by the artifacts they uncover. The students must work together to construct a defensible explanation of real historical evidence, using a wide range of resources — people, on-line collections, books and reproductions, and consultations with experts. The experience proves engaging, empowering, and enlightening. It addresses fundamental educational needs.

(a) Overall, the Archaeotype *project addresses three primary needs:*

Archaeotype, as a strategy for introducing middle school children to ancient history, emerged from explicit educational needs.

(1) *Subject-matter.* In school studies, the overwhelming need is to communicate to children the sense that they can take possession of their knowledge and their future by constructing an active interpretation of it. To do that, children need to build the skills required to make such constructions and to internalize the criteria of good reasoning when confronted with complexity of information and difficult intellectual, social, and historical questions.

(2) *Motivation.* Within the classroom, the need is to cultivate cooperation, rather than competition, as the main motivational device.

(3) *Technology.* In the implementation of computer software for educational purposes, the need is to avoid reliance on the novelty of technology to achieve effects in educational design, and to use the tools, not as sufficient ends, but as means to engage children in exploring substantively rich resources in the world about them.

(b) The applicants identified these needs through reflective practice.

Archaeotype is the work of the New Laboratory for Teaching and Learning, a development lab that is an integral component of the Dalton School, one of the country's pre-eminent K-12 private schools. The leadership of the school and the lab have identified the needs addressed through *Archaeotype* in the course of conducting the school's educational work and in collaboration with leading scholars in the field of education. The identification of needs thus arises from the travails of reflective practice, the elements of which are as follows.

(1) *Subject matter.* Reflecting on historical studies, we find that children unfortunately learn history as a story to be memorized. Clearly children must learn about the peoples and problems of the past. Yet, mastering the universally valuable skills of the historian, contending with diverse information and constructing plausible explanations of its character and content, is of equal value to knowing about the past. Historical and social studies in schools have been dominated by curricula informed with a grand narrative, a learnable sequence of causes and effects, often marshaling novel-like heroes and villains, who commit great and heinous acts. In this context, the teacher learns the script in her early years of teaching. With familiarity she overcomes the initial anxieties of a new teacher stemming from the unpredictability of student responses and from her own incomplete mastery of the script. Given *Archaeotype*'s interactive hypermedia capacities, regardless of the simplicity of the

artifactual database chosen, teachers find it almost impossible to predict the direction of a student's inquiries. The teacher must wait and see what direction students choose before she can begin to be useful as an experienced interpreter of similar realms. Indeed, it is this unpredictability which prevents the educational environment from degenerating into an over-simplified drama in which authentic dialogue is impossible because the teacher anticipates from her experience all the possible lines of the conversants. Consider the difference between an experienced guide returning to the same sites year after year and the experienced explorer who has considerable skill in traversing unknown places but rarely retraces her exact steps. This demonstrates the difference between a teacher in the old scripted tradition, locked into a predetermined tour, and the new teacher able to respond each day to the unexpected choices and problems emerging from the study and research of her students. The student becomes the centering force rather than the worn grooves of the curriculum.

(2) *Motivation.* Owing to their demographics and to the gate-keeping functions they have traditionally served within modern societies, schools have classically relied on the force of competition to inspire students to serious effort. Given the new emphasis on the practical importance of cooperation and collaborative problem-solving in the public conversation about work and productivity, the normal view of encouraging competitive attitudes in schools has been significantly challenged. Although the demographics pertaining to student-teacher ratios have not changed, computers have put in our hands a new means of deploying scarce professional resources. A teacher no longer need position herself in front of a class to instruct a large group. Rather, *Archaeotype* allows student attention to focus on the object of study. Further, results cannot be effectively achieved either within the small group or in the context of the larger project without substantial and constant communication and cooperation. When we describe *Archaeotype* as an example of integrated curriculum, we mean to include both its capacity to be genuinely interdisciplinary (one needs the different disciplines to solve the problems one faces) and its capacity to encourage learning habits that do not require the spur of competition to gain the qualities of dedication, energy and commitment.

(3) *Technology.* Computer-based curricula are often pallid and canned. At their best, computer-based materials can be vivid and full, but often the screen presents abbreviated explanations, simplified representations, and few pointers for the curious to resources outside the system. When this happens, computer-based programs reinforce one of the great problems of the classroom—its tendency to become a bounded intellectual environment where the cultural stimuli are generally sparse. Educational environments need to be rich with quality information and powerful ideas. *Archaeotype* meets this need in many ways. The artifacts that students uncover lead them to reach out to a wide range of interpretative contexts—to on-line resources, to books and reproductions, to people who might have expert knowledge. For instance, in *Archaeotype 1.0* the development team provided students with a list of accessible experts in the different areas of Greek studies to whom they could go

when they wish to discuss problems they encountered. They have also encouraged them to make full use of the Metropolitan Museum of Art, the best local collection of Greek antiquities, and to use on-line collections such as the *Perseus Project* and the video discs on the Louvre collections. Helping student excavators develop a mental model of learning, which focuses the questions they have presented to themselves as the significant challenge, rather than winning the "game" in which these questions may first be encountered, stands as a primary goal of this project, and perhaps somewhat ironically, one of the true potentialities of the new technology in education. *Archaeotype 3.0* should be particularly effective in leading students to quality materials, for The Brooklyn Museum has not only an excellent collection which students can engage through their excavations and unfolding interpretations, but also a very strong curatorial and educational staff that can serve as sources of human expertise, helping students make their interpretations ever fuller and deeper.

(c) Archaeotype *meets these needs by using a networked, multimedia simulation to introduce students to the study of ancient civilizations.*

Prototype versions of *Archaeotype* have given a proof of concept that an archaeological simulation using networked multimedia can lead students to develop well-considered narratives of the past, that they can do it through complex classroom collaborations, and that they will avoid the technological solipsism of relying solely on computers in the process. Our project will carry this concept toward general implementation.

> Recently, at a place in Greece just north of the isthmus of Corinth, and a little more than halfway between Eleusis and Plataea, a farmer was plowing his field when he hit upon a particularly large boulder. When he tried to pull the huge piece out of the soil he could not budge it. So, the farmer enlisted the help of his sons who lived with their young families on nearby farms where they cultivated olive groves and grape vines for the export trade. Together the men succeeded in excavating a chunk of limestone with peculiar striations on one side. The farmer who remembered that his very own father had fished artifacts out of his field many years before knew that the piece of stone was in fact an artifact created in classical antiquity. He also knew that the law required that he inform the Department of Antiquities, an arm of the Greek government, of his discovery and request that an emergency excavation team of archaeologists be sent to the farm immediately. When the team arrived at the farm and had conducted a preliminary observation of the site, the archaeologists recommended that a full-scale excavation be undertaken as soon as the weather permitted. Because of the special relationship that your school has with the Department of Antiquities, you have been given the rare opportunity to join the excavation. You will be a guest in the land of the Ancient Greeks.

Thus begins the sixth grade curriculum module entitled "Lessons From the Soil: The Ancient Greeks," which is a specific deployment of a prototype software package, *Archaeotype*. Technically, *Archaeotype* is a networked, archaeological simulation written for Macintosh computers in the language *SuperCard*. Presently, in addition to the Hellenic iteration of

Archaeotype, there is an Assyrian excavation entitled "Tell Ahmar: An Assyrian Fortress in North Syria." The Assyrian site was built on the success of the Hellenic and is presently being beta-tested in the Dalton sixth grade. The Hellenic, which has run for three successive years at Dalton, is presently being tested at the Juarez-Lincoln School of the Chula Vista Elementary School District in southern California.

Archaeotype allows students to work in small groups to excavate a section of a simulated archeological site. As they dig and discover things, they send them to a simulated lab where they measure, weigh, and begin their research into the nature of their specific discoveries. They are encouraged to use both the resources within the library of the program as well as other resources available outside the orbit of the program such as museums, experts and library materials. The challenges built into the project are intentionally multidisciplinary requiring the use of math, science, history and philology. As the students continue to excavate, they compile a database on the basis of which they are called upon to make inferences about the society and culture of the site. As they try to construct a picture of some coherence, they are encouraged by the team-oriented nature of the archaeological enterprise itself to cooperate with each other to achieve this goal.

Through the *Archaeotype* prototypes, we have strong indications that the software addresses the three primary needs of the project effectively. Evaluators have found that students effectively engage in constructing their own narrative context for interpreting the specific artifacts they uncover and the site as a whole. To do this, they engage in spirited cooperative work as small groups of students work together to understand their quadrant and join periodically as a whole class to make sense of the site as a whole. With such experiences, students effectively avoid technological solipsism, even if they rely primarily on the computer for information and ideas, for the experiences lead students to focus on the historical, interpretative questions, using any and every resource they can — the computers, books, pictures, maps, videos, recordings, people and collections, throughout the school, at home, and in surrounding cultural institutions — to construct a context for interpreting their site and the artifacts they uncover within it.

Over the long run, we intend to develop successive versions of *Archaeotype* in such a way that a school faculty can choose what culture and society should be represented in an excavation. Teachers will be able to construct an excavation around Chinese, African, or Native American materials. They will be able to control the level of complexity of the site through the selection of artifacts in the dig and through the complexity of research resources both within and without the program environment. We propose to move decisively towards these features of the program with *Archaeotype 3.0*, an Egyptian site, which the New Laboratory for Teaching and Learning will develop in collaboration with the Institute for Learning Technologies at Teachers College, Columbia University, and the Education and Curatorial Department of The Brooklyn Museum. *Archaeotype 3.0* will move the concept beyond the prototype stage toward a genuine production version that can distributed widely. We seek support for developing the software and training strategies for preparing teachers in its use. In this way, the project will turn the potential of a prototype into an emerging general implementation.

Through good schools, the young need to learn how to learn, to solve significant problems through the pursuit of their own inquiry. The design of *Archaeotype* helps students to do this. It presents real unknowns to students and provides a context of tools and resources enabling them to work creatively, over a sustained time, developing hypotheses and assessing their merits — criticizing, searching further, and revising. In this process, they draw on a range of intellectual tools and techniques that people usually associate with different subjects — maps, chronologies, graphs and coordinates, measuring standards, geometric and algebraic calculations, ecological analyses, geological distributions, artistic motifs, technological and scientific histories, religious and mythological studies, medical epidemiologies, economic calculations, and so on. Usually, if children have any experience of the powerful tools of inquiry in all these areas, they experience them as the ends, the objects of their labor. Yet for real inquiry and action, these resources are tools, *means* for possibly developing real solutions to real problems. *Archaeotype* enables students to use such resources as means to learning, and will thus help them to form a sense of how to address real difficulties. The more our educational institutions can convey this sense to our children, the more powerfully it will enhance the long-run development of our culture.

(d) The following benefits will result as the project meets its primary needs.

Archaeotype 3.0 will generate specific benefits as a result of the first year of work on it and through its subsequent development. The first-year activities will result in the following:

(1) A curriculum unit on ancient Egypt will have been developed. It will be suitable for use in the sixth through tenth grades and schools will be able to install it in classrooms either from a CD-ROM at the location or from a high-speed wide-area-network link to the development sites at Dalton, Teachers College, and The Brooklyn Museum.

(2) A generic excavation interface and retrieval resources for *Archaeotype* will have been developed, a major step in making it possible to distribute the program generally to schools and colleges.

(3) The Brooklyn Museum will have created digital representations of many objects in its renowned Egyptian collection and made these representations, and curatorial support resources pertaining to them, accessible via wide-area-networks.

(4) An initial cadre of teachers will have learned to use powerful constructivist pedagogical tools with their students, and they will have begun to introduce new curricula and laboratory-based strategies in their schools.

(5) Assessment tools and strategies for documenting how and what students learn as a consequence of working with the new curricula will have been prepared.

(6) Feasibility of an important curriculum delivery model—one which will use high-speed wide-area-networks to provide access to quality collections of visual, audio, and video material—will have been tested.

With the subsequent development of these specifics, benefits of considerable general import to the nation can accrue:

(7) Culturally, *Archaeotype* will contribute to educating citizens who have *learned how to learn*, a quality essential in an ever-changing information society.

(8) Socially, it will accustom students to learning in creative collaboration with others, an indispensable capacity for coping with the divisive stresses that beset our communities and economies.

(9) Technically, *Archaeotype 3.0* will show how schools, universities, and cultural institutions can modularize and link their educational resources and efforts in ways that will avoid inhibiting entanglements oven intellectual property rights while engendering transformative improvements in education.

Three: Plan of Operation

Our plan of operation involves the following steps:

(a) Design and development of *Archaeotype 3.0*.

(b) Selection of schools as implementation sites.

(c) Training of teachers for introducing *Archaeotype 3.0* in the selected schools.

(d) Design of assessment strategies for evaluating student achievement in the selected schools.

(e) Supervision of the first pilot test in the selected schools and the formative evaluation of the test to ready *Archaeotype 3.0* for more general use.

The first four steps will take place concurrently during the first year of the project. The last step will follow in subsequent years, along with extensions of the first four.

(a) Design and development of Archaeotype 3.0.

To create *Archaeotype 3.0* we will design and develop three distinct, yet related, components:

(1) An educational scenario and interface which will present the problematic of the excavation to a class of cooperating students. This is the component that students will see on the screen of their computers as they proceed through the excavation. A group within the New Laboratory for Teaching and Learning will have primary responsibility for this component, which we will call the Pedagogical Group, directed by Dr. Frank Moretti.

(2) A representation of the artifacts to be found in the site and of the contextual materials — explanatory texts, pictures, drawings, maps, and videos that students can call up on-line help make sense of the artifacts they excavate. A group centered at The Brooklyn Museum will have primary responsibility for this component, which we will call the Reference Group, directed by Deborah Schwartz.

(3) A set of on-line tools such as database management programs, hypermedia notebook tools, image-analysis tools, and the like that students and teachers can employ in setting up and carrying out their excavations and reporting on their results. A group

drawing from the New Laboratory for Teaching and Learning and the Institute for Learning Technologies will have primary responsibility for this component, which we will call the Tools Group, directed by Robert McClintock.

In addition, a fourth group, the Assessment Group, directed by Dr. John Black, will work concurrently to develop some special student assessment tools (see below, Section 3d).

The Pedagogical Group. The staff of the New Laboratory, along with key teachers associated with earlier versions of *Archaeotype*, have extensive experience with the pedagogical strategies employed in the program. Each version includes a carefully contrived assignment, designed to take six or more weeks to complete. This assignment informs the choice of materials in the site and the resources available for interpreting them. It is the most important and difficult part of the program to develop from an educational point of view. The main features of it should be created by the Dalton staffs as early as possible in the life of the project. They will start 1993-94 engaging in a general survey of Egyptian archaeology, in particular, becoming fully familiar with the Egyptian collections of The Brooklyn Museum. The Museum is currently reinstalling its Egyptian collection, which will reopen early in November 1993. At that time, the program development staff will start discussing with the curatorial staff there various options for the design of the excavation. By January 1, 1994, they should have a general specification sheet for the excavation, setting its location, the chronological span of artifacts within it, the cultural typology of its main components, and an inventory of the intellectual constructions that students are likely to embark upon in the course of the excavation. A preliminary version of the assignment statement should be complete by that date as well. The Pedagogical Group should then turn to laying out the excavation interface which needs to be carefully designed to engender the appropriate division of labor within a class, to be clear and engaging to students using it, and to be coherent and efficient throughout the full life of the excavation. In developing the excavation interface, the Pedagogical Group will need to work closely with both the Reference Group and the Tool Group.

The Reference Group. The Brooklyn Museum has one of the premier collections of Egyptian antiquities and an excellent curatorial and education staff. They have already started to develop digital representations of key holdings. The Reference Group will work with the Pedagogical Group to determine how the objects placed in the site should be represented and to select, digitize, and organize the supplementary materials that will be available on-line as resources to help excavators to make sense of what they find and to interpret objects and the site as a whole. The Reference Group will need, at first, to concentrate on developing the representation of objects in the site. They will need to work closely with the Pedagogical Group to make sure the representation of objects they prepare reflects the educational rationale of the site and the objects in it. In addition to developing the digital representations of the objects in the site, the Reference Group needs to select and create the on-line interpretative resources that will be available to the excavators as they work, uncovering objects and developing their interpretations of them. These materials should be authoritative from the scholarly point of view, and even more importantly, effectively usable in helping student archaeologists formulate sound, insightful hypotheses about what they are discovering. In developing the representation of objects in the site and of interpretative resources, the Reference Group will need to work closely with the Tools Group to make sure that the digitized representations they develop conform to the data standards required by the tool set designed for the program.

The Tools Group. Both the other groups concentrate on the *what* of the educational experience. The Tools Group needs to concentrate on the *how*, creating tools that will work, insofar as possible, generically, with any site layout and representation of its contents and interpretative resources. From prior versions of *Archaeotype*, we have a good working understanding of the design requirements for many tools to be build into *Archaeotype 3.0.* By November 1, 1993, the Tools Group should have a full requirements statement prepared for discussion with the other two groups. This should be finalized by January 1, 1994, and two distinct implementations need then to be developed. The first will allow for interim testing in settings where powerful wide-area-network linkages are not in place, a constraint we expect to pertain in most of our school locations. In this version, both the excavation interface and the representations of objects in the site and the interpretative resources will reside on one local-area-network. The second will allow for the testing of the typology that we expect for a full production version. In it, the excavation interface and the main tool set will reside on classroom computers, linked together by a local-area-network, while the representation of the objects in the site and the interpretative resources will reside on a database server at The Brooklyn Museum accessed by high-speed wide-area-network links. This second version will not pose significant difficulties in the design of the tool-set. In the near future we expect there to be a significant market for both formats, and as sophisticated wide-area-network links become common in schools by the end of this decade, the networked version will become standard.

Thus all three development groups will be working in parallel during the 1993-94 academic year. *Archaeotype 3.0* should be up and running in a preliminary version at the Dalton School, at Teachers College, and at The Brooklyn Museum by June 1, 1994, in time to prepare for the Summer Training Workshops in July (see below, Section 3c).

(b) Selection of schools as implementation sites.

Selecting implementation site schools will take place during the 1993-94 academic year. With the I-CM Project, for teaching science with the Interactive-Colloquium Method that was funded by the Secretary of Education, the DeWitt Wallace-Readers Digest Fund, and the Helena Rubinstein Foundation (see appendix), the New Laboratory for Teaching and Learning has worked collaboratively with diverse schools the in New York City Public School System and it has maintained these relationships. The New Laboratory for Teaching and Learning has also been the center for the Mayor's Partnership for Public and Private Schools for New York City. In addition, the Institute for Learning Technologies at Teachers College has had several funded projects with public schools the in New York City system and through the New York Youth Network, a computer-based bulletinboard for at risk youths, it cooperates with a variety of community-based groups. The Brooklyn Museum itself has a very active public education program, running funded summer institutes for public and private school teachers on ancient Egyptian art and archaeology, as well as other topics.

An Advisory Board will, among other things, help the Project Directors select schools as implementation sites. The board will include the following, who have agreed to serve:

Anthony Alvarado	Superintendent of District Two in the New York City Public School System.
George Bond	Professor of Anthropology and Education and Director of the Institute of African Studies, Columbia University.
Ann El-Omami	Curator of Education at the Cincinnati Museum of Art.
Ogden Goelet	Assistant Professor of Egyptian Language and Literature, New York University.
Toni Schmiegelow	Executive Director of the City Volunteer Corps.

In past collaborations, we have learned that schools should be selected close to the actual start of implementation at the site and that broad interest in the project within the school, in addition to support from the top authorities, is essential to achieve success. Hence, we will use a range of criteria for selecting potential partners, among them:

(1) The cultural diversity of the school itself will be a very significant criterion. Our expectation is that the school must in some way represent the range of students in the New York Public School System and therefore to some extent the range of students in most urban settings.

(2) Whether or not a school has sufficient technical base without requiring extensive upgrade to sustain the project through classroom use.

(3) The level of faculty enthusiasm for projects of this type and their willingness to work for approximately five weeks in the summer before the actual implementation of the project in the school.

(4) The full support of the principal of the school and a clear indication that the principal understands that the new technologies can enhance learning in the direction of constructivist pedagogical principles.

(5) The central support of the superintendent of whichever district each school was in.

The final deadline for the selection of the five public schools, one from each of the five boroughs of New York, will be May 1st. In addition to these five school sites, we will implement *Archaeotype 3.0* at four additional locations: the Dalton School, where the New Laboratory for Teaching and Learning has developed prior versions of *Archaeotype;* Boys Harbor in upper Manhattan, with which the New Laboratory has a preexisting collaboration; the New York City Museum School, in the creation of which The Brooklyn Museum has been a moving force; and the Juarez Lincoln School from the Chula Vista Elementary School District in California, which has already become a test site for earlier iterations of *Archaeotype*.

The calendar for the process of selection is as follows:

10/15/93:

Using the Advisory Board and our own educational network including Teacher's College and public school collaborators we will collect a series of recommendations of at least 15 schools that might meet the above-mentioned criteria.

10/15/93 to11/15/93:

The director will make school visits, which will include a demonstration to the administration and faculty of the interested school of earlier iterations of *Archaeotype* and an explanation of the educational principles involved as well as a clear indication of where *Archaeotype* can supplant in an effective way the traditional curriculum from their specific curriculum outline. The school visits will also involve a review of school facilities and interviews with the teachers and administration in order to determine levels of interests. Those schools that are still interested after the visit will express that interest by formally applying for participation in the project by December 1st. We will seek to get by December 15th support from the superintendent of the school district of each of the applicants.

1/10/94:

The project will make a commitment to five schools and three schools on the waiting list, with the goal that each of the five be from a different borough.

(c) Training of teachers for introducing Archaeotype 3.0 *in the selected schools.*

From the schools finally selected, four teachers will be chosen with the principal with the goal being that at least two be social studies teachers preferably from the 5th and 6th grades and two others from other disciplines but having an interest in the project. It would also be desirable that one of the two non-social studies teachers be a librarian since the project is significantly concerned with information resources on the direction that the shaping of intellectual information resources in a specific school goes. The criteria for selecting the four teachers will be:

(1) diversity;

(2) motivation and interest;

(3) intellectual preparation for working in a constructivist educational environment, which

may come from a variety of experiences, ranging from teacher-preparation courses to work on other projects that have similar essential principles but not the technological base of *Archaeotype*.

The calendar for selection process will be as follows:

1/15/94: Principals make recommendations.

1/15/94 to 2/15/94: Teachers will be interviewed by the project director in conjunction with a team from the development group and a representative of the advisory group.

2/28/94: The four teachers from each of the five schools will be selected by the above group.

4/1/94: Description and demonstration of the prototype will take place and a workshop discussion of its use, power and curricular placement.

7/1/94 to 7/31/94: Summer Training Workshop will take place. Credit will be available for taking this workshop through Teachers College or in place of credit teachers taking this workshop will receive a $1,000 stipend.

The five weeks of the workshop will be allocated as follows:

Week 1: Basic training in the use of *Archaeotype* and an introduction to the philosophical premises and the future of interactive networked multimedia.

Weeks 2 & 3: The twenty teachers, under the supervision of the summer training institute personnel, will do the simulated excavation with daily debriefings exploring the educational possibilities and problems implicit in the prototype.

Weeks 4 & 5: Teachers with their supervisors will work out the specific curriculum adaptations necessary for each school which take into account the material constraints of the school, its information resources, and specific characteristics of its student population.

(The Summer Institute will be run collaterally and cooperatively with The Brooklyn Museum's Egyptian Summer Institute for Teachers.)

(d) Design of assessment strategies for evaluating student achievement in the selected schools.

In Section 6 below, we describe what we intend to do to evaluate the effectiveness of *Archaeotype 3.0* as an educational resource. The subject of evaluation there is the program we propose to develop. A significant element of the program to be developed consists of assessment strategies for documenting what students learn through *Archaeotype* and providing them helpful feedback that can help make their studies bear optimal fruit. Here the subject of assessment is the student.

Traditional assessments — quizzes and essays keyed to the text and the teacher's glosses to it — are not particularly relevant to understanding student performance with *Archaeotype*. Indeed, traditional assessments will be out of harmony with *Archaeotype* and would probably deflect students' effort into unproductive paths. We instead seek to develop three types of assessment strategies that are consistent with the goals and procedures of the program — embedded, portfolio, and transfer assessment.

Embedded assessment characterizes much real scholarly inquiry and problem-solving activity, especially as it is conducted by working groups. Embedded assessment opportunities will be integral components of the work-flow in the *Archaeotype 3.0* pedagogy. Once a week each class, working together on the full site, should meet as a whole to present key findings, to explain preliminary hypotheses, and to discuss how to proceed. Each subgroup assigned to a quadrant should continually discuss how each can best contribute to moving the excavation forward and brainstorm about the artifacts they have found. The whole process of inquiry moves forward as students share and criticize preliminary findings, searching out further information, developing and overturning possible hypotheses. All this is the embedded assessment integral to active inquiry and study.

Portfolio assessment results because students work together to produce on-line site reports presenting their selection of key artifacts and their interpretations of the site based upon them. These reports will reflect both individual effort and collaborative accomplishment and a significant component of the pedagogical design will be to provide a framework helping students to develop these reports. Two cycles of formative evaluation are already available. *Archaeotype 1.0* has students learn the rudiments of *Hypercard* and then use it to create their reports. In some instances this worked very well and in others students found the added dimension of having to do some programming to present their analyses too daunting. In *Archaeotype 2.0* a preprogrammed framework for exploring interpretative hypotheses has been included. Observations of the first group of students using this tool are currently under way, and these findings will help further develop the site reporting resources built into *Archaeotype 3.0*. The basic goal with these resources should be to permit students to pose the problematic of the site and specific artifacts, to link to visual and textual resources for dealing with these problems, to incorporate new information into the system that they find useful, and to present, weigh, and explain hypotheses about their site and artifacts that seem to them compelling. The portfolio assessment tools will allow students to preserve their accomplishments and will provide work that teachers can formally assess. The educational design of *Archaeotype 3.0* will include a set of guidelines for the formal assessment of site reports.

Transfer assessment will involve the creation of special problem-solving challenges to be administered to groups that have completed *Archaeotype 3.0*. The theory here is that learning to learn is the most important achievement that can result from *Archaeotype*. A good way to assess whether this is happening would be to devise group problem-solving challenges that would show the degree to which students had internalized key strategies and capacities through their experience with *Archaeotype* and could transfer the use of them to the new setting. The evaluation component to be developed by Professor John Black will center on creating such resources.

(e) Supervision of the first pilot test in the selected schools and the formative evaluation of the test to ready Archaeotype 3.0 *for more general use.*

The full pilot test of the Egypt project will take place simultaneously at nine locations during the 1994-95 school year:

1) The Dalton School, where the New Laboratory for Teaching and Learning has developed *Archaeotype*.
2) The Juarez Lincoln School, in the Chula Vista Elementary School District, where a team from San Diego State University, led by George Mehafy and Bernard Dodge, are presently evaluating use of the Greek *Archaeotype* as a unit in sixth-grade social studies.
3) The Museum School—one of the New Visions Schools supported by the Fund for Public Education and directed by the Board of Education and the New York City Museum Consortium.
4) Boys Harbor, a privately funded school for at-risk youths in Harlem.
5-9) The five public schools selected in accordance with the aforementioned process.

The supervision of the actual pilot tests will involve visits by summer institute faculty, on-line communications through electronic mail and monthly colloquia at the Institute for Learning Technologies and the New Laboratory for Teaching and Learning focused on problems emerging in the process of implementation. The personnel conducting the supervision and training during the process of actual implementation will include graduate students participating in the Full-time Internship Cohort Masters Option, cosponsored by the New Laboratory for Teaching and Learning and the Institute for Learning Technologies in the Department of Communication, Computing, and Technology at Teachers College. Teachers and designers from the New Laboratory for Teaching and Learning, who have had experience in working with simulated archaeological excavations, such as Dr. Neil Goldberg, will also supervise the implementations, as will professors from the Institute for Learning Technologies and museum personnel who will have been effectively involved in the actual development of the intellectual characteristics of the site.

Through the process of supervision, formative evaluation information on the design and implementation of *Archaeotype 3.0* will be gathered and communicated to the three groups — the Pedagogical, Reference, and Tools Groups — that developed the program the previous year. The information will allow them to improve the excavation interface, revise and expand materials on-line that serve as interpretative resources, and to debug and perfect the operation of the connections between the interface and the representations of objects in the site. In addition, a Documentation Group will work with teachers at the nine implementation sites to develop manuals and teachers guides that help new users get the program to operate.

During the process of formative evaluation, the design of the student assessment tools will also be tested.

Four: Personnel

The key people in the project have extensive experience and excellent qualifications. Here are short biographies of the most important. Full resumes are in an appendix.

Director, Pedagogical Group: Frank A. Moretti, Ph.D. is presently Associate Headmaster of the Dalton School and Executive Director of the New Laboratory for Teaching and Learning. He originated the educational use of simulated excavations at Dalton and managed development of the Greek *Archaeotype*, which became the core of the Dalton Technology Plan, an effort to integrate networked multimedia throughout the Dalton curriculum, K -12, financed at about $1 million per year. Moretti has been involved in innovative curriculum design for twenty years and was responsible, before coming to Dalton in the early 1980s, for the design of Bloomfield College's Teacher Training Program, New York University's Bachelor of Education Program for Adults, as well as for a range of projects related to the K-12 curriculum in public and private education. His most recent publication is "A Classicist Conversing with the Conservatives," due for publication in the *Teachers College Record* in summer 1993.

Director, Tools Group: Robert McClintock, Ph.D., directs the Institute for Learning Technologies at Teachers College, Columbia University, where he is Professor of History and Education. McClintock helped to develop the Dalton Technology Plan and serves as one of its Co-Directors. From 1985-89 he chaired the Department of Communication, Computing, and Technology at Teachers College. He has published and lectured widely, here and abroad, on issues of technology and education and on the history of educational theory. His most recent book, *Power and Pedagogy: Transforming Education Through Information Technology,* will be published late in 1993 by the Educational Technology Press.

Director, Reference Group: Deborah Schwartz, B.A., Vice Director for Education at The Brooklyn Museum, has been with the Museum since 1982. She previously held positions at the Landmark's Preservation Commission; the Institute of Fine Arts, New York University; and the Museum of Contemporary Art, Chicago. Ms. Schwartz received her B.A. in art history from Northwestern University and is finishing her M.A. from Queens College. She is currently Co-Chair of the Museum Education Consortium, and Vice President of the Gallery Association of New York State. She also teaches in the Master's degree program at the Bank Street College of Education. At The Brooklyn Museum, Ms. Schwartz is responsible for overseeing the planning and implementation of all educational and interpretative programs for adults and children.

Director, Assessment Group: John B. Black, Ph.D., is Professor of Computing and Education at Teachers College, Columbia University. Before coming to Teachers College in the mid 1980s, he taught cognitive science at Yale University. Dr. Black directs the Center for Literacy Studies at Teachers College and has wide experience in the design and implementation of educational software and alternative assessment measures. He is currently managing the effort to develop new assessment measures in the Dalton Technology Plan. Dr. Black has published numerous research studies on the study of cognition and its bearing on the design of instructional efforts.

Five: Budget Discussion

The *Archaeotype 3.0* Project will be embedded in ongoing efforts by the key participating groups, with the result that it will benefit from substantial cost-sharing. The New Laboratory for Teaching and Learning has already developed two versions of *Archaeotype*, with great success in the classroom. The new version will benefit from this experience and make it more ready for dissemination to schools throughout the nation. The Dalton Technology Plan is one of the most advanced efforts to integrate technology, K-12, in an excellent school and the experience and infrastructure of this effort will make the *Archaeotype 3.0* project far more cost-effective. Likewise, The Brooklyn Museum has a premier collection of Egyptian antiquities. The availability of such pre-existing resources will enable the project to create and test software of great power and quality for a modest additional investment.

Explanations of specifics in the budget will be found with the budget forms.

Six: Evaluation Plan

During the first year of the *Archaeotype 3.0* project, we plan to gather extensive data to serve as a base line for evaluating the performance of the program in its pilot tests. We will document the achievements and cognitive skills of two groups thoroughly—those of the students who in the following year will work with *Archaeotype 3.0*, and those of the students who complete this year the courses into which *Archaeotype 3.0* will be introduced next year. Information on the first group will provide a base line for understanding the developmental effects of working with *Archaeotype 3.0*. Information on the second group will provide a base line for comparing the achievements of those working with *Archaeotype 3.0* to those who have not.

In gathering data on the first group, we will lay a foundation for evaluating key expectations about the effects of a constructivist program such as *Archaeotype*. We would assess the full range of cognitive skills as measured against Bloom's taxonomy of cognitive skills. Here are some specific sorts of claims we would like to test, as these are the distinctive claims that indicate the unique and powerful value of the program.

- Students who have worked with *Archaeotype 3.0* will integrate factual information into explanatory arguments more often than students who have not.

- *Archaeotype* students will be more likely to extract and express principles from what they learn than other students.
- *Archaeotype* students will more frequently solve problems applying mathematical or other formal strategies.
- *Archaeotype* students will seek to use information resources available in their immediate environment to solve novel problems more frequently than other students.
- Given a problem, *Archaeotype* students will focus on it in conversation together more fully than other students will.
- *Archaeotype* students will more often mobilize teachers and texts, less as authoritative answers, and more as resources to help them construct or determine answers, than will other students.
- In writing or speaking about causal explanations, *Archaeotype* students will more often weigh multiple hypotheses, recognizing pros and cons for each, than will other students.

During the first year of the project, the evaluation team will refine the list of claims we seek to test and will gather base data for use evaluating these claims the following year.

Seven: Institutional Resources

The *Archaeotype 3.0* Project will combine the resources of significant institutions — the New Laboratory for Teaching and Learning at the Dalton School, the Institute for Learning Technologies at Teachers College, Columbia University, and the Educational and Curatorial Department of The Brooklyn Museum. Fuller information on these institutions is included in the appendices. For a complete description of the Dalton Technology Plan, see *Risk and Renewal: First Annual Report of the Phyllis and Robert Tishman Family Project in Technology and Education — 1991-1992* (New York: New Laboratory for Teaching and Learning, 1992). For a full description of The Brooklyn Museum resources, see Richard A. Fazzini, *et al. Ancient Egyptian Art in the Brooklyn Museum* (New York: The Brooklyn Museum, 1989,)

In addition, the resources of two substantial school districts — the New York City Public School System and the Chula Vista Elementary School District in San Diego, California — will participate as implementation sites.

***

NSF Grant Application—*Project Galileo*: Helping All Students Achieve High Standards of Scientific and Mathematical Understanding Through Participatory Study

Project Narrative

I: Objective

To develop, fieldtest, and prepare a major curriculum innovation for national dissemination.

Project Galileo, a high school science course that uses digital technologies to give students access to the practice of astronomy, helps all students achieve high standards of scientific and mathematical understanding. With the funding sought through this proposal, the New Laboratory for Teaching and Learning at the Dalton School will complete and integrate the materials that will support student work in the course and develop a program preparing science teachers to introduce *Project Galileo* into their schools. During the 1994-95 school year, we will field test *Project Galileo* in ten New York City schools and further revise both the materials and teacher preparation strategies on the basis of this experience. At the end of the project period, this innovative curriculum will be ready for distribution to schools throughout the country.

II: Need

(a)The educational needs addressed by the project

Even in very good schools, science and mathematics increasingly split the population into a small group of students who catch on and do very well and another set of those who have difficulty attaining high standards of understanding. Key characteristics of science itself are at the root of this educational difficulty. The phenomena with which the core sciences deal are highly abstract and inaccessible in ordinary everyday experience. Instruments suitable for investigating outstanding questions are costly and hard to handle and data often require extensive mathematical analysis after they have been acquired to become meaningful. Hence the questions driving scientific inquiry often remain obscure to students, making it virtually impossible for them to achieve high standards of understanding.

Astronomy well exemplifies these tendencies. Throughout ancient, medieval, and early modern history, astronomy was securely one of the seven liberal arts, a core component of the curriculum. What fills the heavens above, so strangely different by day and by night, was a set of profoundly puzzling but inescapable questions put to people by their everyday experience. The resulting inquires were intrinsically intriguing and practically consequential in keeping both time and the calendar. Through the nineteenth century, astronomy was a significant component of the school science curriculum, and the orrery and the tellirion were instructional instruments present in nearly every school. The situation changed because the practice of astronomy changed.

During the twentieth century, the study of astronomy in schools greatly declined. The science of astronomy became far more powerful than it had been, but that very success in the observatory far atop the distant mountain made the subject less and less appropriate in the school. Relative to the layman, astronomical research became highly esoteric. Telescopes became very big and very expensive. Complex optical and spectroscopic instruments increasingly mediated the gathering of data through those telescopes. As observation penetrated further and further out in space and back in time, the logistics of using the catalogue of objects that had been charted and observed, became very difficult to manage, a skill marking the gulf between novice and expert. And finally, working astronomers and astrophysicists had to use very advanced mathematical concepts and to engage in voluminous, tedious calculations to make sense of their data. Astronomy ceased to be generally accessible and had to be presented, when presented at all, almost entirely through textbook abstractions. The astronomers' questions became abstract to ordinary people and the non-specialist study of their findings became a passive process of learning what others knew.

Digital technologies are making it possible to reverse the processes through which science education has been losing its immediacy. The New Laboratory for Teaching and Learning at the Dalton School has been created to find ways to use these technologies as means for improving the quality of attainments possible in education. A general principle of curriculum innovation being developed through it is that digital technologies will provide students of diverse ages and wide abilities with meaningful access to the questions and resources of advanced disciplines in the sciences and humanities. We have deigned *Project Galileo* as a specific instance of this principle.

Computers may be particularly helpful in astronomy in enabling all students to achieve high standards of understanding. The reasons for this possibility arise from the way computers are affecting the practice of astronomy itself.

1) Observations from telescopes and space probes, acquired in digital format, can be stored, reproduced, and sent inexpensively via networks to most anyplace, including the school classroom.
2) Complex analytic instruments can be simulated in the computer and applied effectively to confusing data, allowing students with little prior training to extract sophisticated insights from the digital data.
3) Computer-based data management techniques allow relative novices to work productively with the full base of acquired observations in the field.
4) Computer programs make it possible for students to mathematical computation and graphical representation to work with astronomical concepts in ways that are both rigorous and intuitive.

Such effects of the digital technologies alter the practice of astronomy itself and profoundly alter its potential relation to the classroom. *Project Galileo* is a thorough effort to take advantage of these changes in order to reintroduce the study of astronomy in the school. If astronomy can regain a core place in science education, much will be gained for astronomy is one of the great domains of interdisciplinary inquiry, drawing mathematics, physics, chemistry, and biology together in an exciting inquiry into the origins of the universe and of life.

b) A working alternative created through reflective practice.

For a number of years, the Dalton School has had a popular elective astronomy course for juniors and seniors, most of whom are not science majors. The appeal of this course over the years shows that the basic questions of astronomy continue to excite the imagination of students, however esoteric the practice of astronomy may have become. But the problem of delivering the course by traditional means illustrated the difficulties of bridging the distance between the high school classroom and astronomy as a field of research.

A senior science teacher, who has much charisma as a lecturer and much authority as the co-author of a successful college textbook in astronomy, taught the Dalton astronomy elective.[1] Until recently, students learned the course content from lectures and the text, but the basic problem was that they often did not *understand* the material because they could neither personally entertain the questions that led to its discovery nor could they perform the intellectual operations required for its development. "The students enjoyed hearing and learning about astronomy," Malcolm Thompson observes,

> but they remained external to it as a process of thought. Little opportunity was available to them to engage their intellects in the experience of doing astronomy. Without that experience, they remained unable to make original proposals in science within the constraints of physical law. They were even less able to initiate a course of inquiry once a proposal was made. While they learned some interesting facts, they retained their feeling of lack of intellectual entitlement within the context of the discipline. The activity remained passive.

In the summer of 1991, Dalton's New Laboratory for Teaching and Learning received substantial funding to integrate information technologies throughout the school's curriculum. Astronomy immediately became a prime locus of effort. Malcolm Thompson completely redesigned his course, setting aside the text and giving lectures up, substituting a series of computer-based activities and tasks that encouraged students to plot their own pathways through real problems of the field. The resulting course reshapes the intellectual experience of students by using digital technologies to give them access to the practice of astronomy. This computer-mediated, direct access to the practice of a science is the key to participatory science study and it promises to enable all students, not only a few, to attain high standards of understanding.

During the past two school years, Malcolm Thompson and the New Laboratory for Teaching and Learning have developed an effective, project-based astronomy course. It does not use computers to teach knowledge about astronomy to students; rather it uses computers to provide students access to the observations and techniques that astronomers use in pursuing their subject. Throughout the school, networked computers give access to an information landscape that uses a desktop planetarium program, combined with images from NASA, NOAA, working observatories, amateurs, and digitized versions of the Palomar survey plates, along with comprehensive databases from the Astronomical Data Center. Students work with these materials using standard software: image processors, spreadsheets, database management programs, plotting programs, word processors, image scanners, the Internet, and the like. As a significant side effect, students consequently become highly adept with computers.

To take full advantage of such resources, students follow designed sequences of activities, working through real problems in small groups with the teacher. The presence in the workspace of multiple computers, laden with astronomical resources and "friendly" software to access and analyze the resources, provides students a measure of control over authentic scientific materials and the tools for manipulating them in a meaningful way. The course now comprises eight primary topics; the heart of each is a three- to-six week assignment that defines a stream of extended tasks for students to pursue individually and in pairs, using the computers and other hands-on materials.

Constructive work on these eight topics by students constitutes the primary activity of the course. The design of this work takes advantage of digital resources to diminish the distance between the activities of astronomers and those the students can perform. Through the computer they have access and control of working images and data sets. With powerful image processing software and the like, they can analyze the red shift and follow the spectroscopic composition of stars. The planetarium program, available whenever they need it, allows them to internalize the coordinate systems used for mapping the sky and they become adept at using the cataloguing and reference systems for managing stellar objects. They can attend to the conceptual problems of tracking and measurement, leaving the labor of calculation to the computers.

All students in the course achieve high standards of astronomical understanding because their understanding develops as they perform the stream of tasks, which have been set up so that each student will successfully complete every task. It is not simply that the teacher is part of the class to ensure, as overseer, that each student completes the tasks. The teacher is there, as participant, to help each student, in the measure needed, to complete the tasks. This change is significant, making the class workspace one of a common enterprise where students learn together as apprentices with a master.

Typically, the first class of each week meets in conference to set the "week's work" by identifying the task deadlines with estimates of how much time each will take. In these conferences, some negotiation takes place and the students must make a plan of work for the week. The teacher indicates any other scheduled classes for demonstrations, lectures, or group activities, but for the most part the students are on their own, without a formal schedule, to complete their work independently, in consultation with other students, or with the teacher, as the need may be. The amount of work required each week exceeds the amount for scheduled classes by a factor of at least two.

At Dalton, the astronomers' workspace opens for business daily at 7:30 a.m. and is available continuously until 6:00 p.m. During that time, students in varying numbers do their work in collaboration with the teacher and with each other. From the student point of view, the explicit goal is to complete designated tasks. But each task has in it implicit, designed challenges which require interaction with the teacher or with other students who are more knowledgeable or more accomplished with respect to the task. The typical day involves work on the computers or with other materials interwoven with a series of highly focused conversations among small groups of students, or between students and teacher. Much learning takes place through these conversations, as happens in the ordinary practice of science.

Through these encounters, the pedagogical key to *Project Galileo*, the content and the sense of the subject unfold in the atmosphere of a scientific research endeavor. Most importantly, the new format does not split the course population into the few who get it and achieve well and the others who do not and benefit little. Instead, all the participants complete the course achieving a high standard of astronomical understanding. Students gain a working knowledge of what astronomers do and they have internalized the major intellectual constructions essential in the conduct of astronomy. The basic strategy in *Project Galileo* is participatory science study: the students, using professional level materials in a task-oriented partnership with the teacher and other students, develop a feeling of kinship with the practitioners of the scientific community.

A senior drama major in the astronomy course, Elizabeth Davis, eloquently describes her experience with participatory science study:

> Much of the knowledge I have acquired in Astro has evolved in my brain as I proceeded through a task. I acquire knowledge by wrestling with a problem until it solidifies and makes sense to me. Then I am able to move on and teach other students what I have come to understand. I think that is a crucial phrase — we do not 'learn' as much as we 'come to understand.' This somehow makes the material more immediate and the struggle to understand becomes personal so the end product of knowledge is more rewarding and its quality is greater than that of other classes."

If this strategy can be transferred to other schools, a powerful means for helping all students achieve high standards of scientific and mathematical understanding will have been developed.

(c) The current challenge: dissemination and teacher preparation

Introduced at Dalton in the 1991-92 school year, *Project Galileo* has developed rapidly with considerable institutional effect. Students see their activity as a six to ten hour work week, intellectually and socially rewarding, through which their knowledge of astronomy and computers deepens from engagement in the inquiry. Productivity and attaining the status of "knowledgeable person" are valued assets in the community of collaborating learners. Students in the course think they do more work in it than in any other course, and they describe the rewards with pride and enthusiasm to friends and to faculty members. Other students seem to wish to be a part of it as course enrollment is rising and juniors who took it want a follow-on version for their senior year.

Faculty members, in and outside the science department, query project staff and seek advice on implementing a similar pedagogy in their courses. Some of the tasks for the astronomy course and the materials to support work on them have been adapted in parts of the fourth and eight grade science courses at Dalton. Materials pertaining to geophysics and how life originated and evolved have been extended for use in tenth grade physical science. Likewise, efforts by the chemistry teachers to redesign their courses are following the strategy in the astronomy course of using the computer to provide access to the data, questions, and resources of researchers in field. In such ways, *Project Galileo* has caught on at Dalton and we seek support with this proposal to see if it can be transferred to other schools, especially ones with more constrained resources and less advantaged student populations.

In order to prepare *Project Galileo* for wide dissemination to schools throughout the nation, three things need to be done:

1) **Materials**. The course topics and the set of tasks associated with each need to be developed further and the materials to support independent student work need to be expanded and made available in a form that schools will find easy to install, maintain, and use (see below, III b&e, pp. 244-, pp. 248-, for a fuller discussion of our plans for materials development).
2) **Teacher Preparation**. A program of teacher preparation needs to be developed that will ensure that teachers have sufficient command of astronomy to oversee the intellectual apprenticeship of students to the field and that they comprehend how to make the pedagogy associated with it work (see below, III c&d, pp.245 -,247 for a fuller discussion of our plans for teacher preparation).
3) **Pilot Testing and Formative Evaluation**. During the 1994-95 school year, *Project Galileo* will be introduced into ten selected schools that reflect the diversities of New York City so that we can formatively evaluate both the materials and the teacher preparation strategies and ready them for general distribution see below, III f, pp. -249, for a fuller discussion of our plans for pilot testing).

We seek funding for *Project Galileo* from January 1994 through June 1995 to develop and deploy appropriate materials and teacher preparation activities in ten diverse New York City schools. We plan to concentrate on New York City simply for reasons of efficiency in developing the materials and teacher preparation techniques. At the conclusion of the grant period *Project Galileo* should be ready for a national effort at dissemination of the course and the strategies of science education embodied in it.

(d) Benefits to the participants

As *Project Galileo* makes the issues, tools, and strategies of practicing astronomers accessible to ordinary students in the high school classroom, a significant range of benefits results.

1) A collection of resources enabling students and teachers to participate in the work of astronomy will have been assembled and prepared for general dissemination to schools.

2) A full set of topics and student tasks within those topics will have been developed, with introductions to both the general study strategy and to each component, along with detailed guides and materials lists. These will have been fieldtested with diverse school populations.
3) Student evaluation resources, appropriate to the material and style of participatory study of *Project Galileo*, will have been developed and included in the course resources.
4) A program of teacher preparation for use of the materials will have been developed and tested with New York City teachers working in diverse school settings.
5) The whole ensemble will have been fieldtested in ten schools, with formative feedback incorporated into the materials and teacher preparation plans as these are readied for general dissemination across the nation.
6) Extending methods of participatory science study, integral to *Project Galileo*, to other parts of the high school science curriculum will have been initiated.

With the subsequent development of these specifics, benefits of considerable general import to the nation can accrue:

7) Culturally, a way of making science in its full complexity accessible to students with diverse backgrounds, interests, and aptitudes will have been prototyped and readied for wide dissemination.
8) Socially, over time, the methods of participatory science study pioneered in *Project Galileo* can alter the way the general public relates to advanced scientific work, diminishing the sense that it is the domain of esoteric experts, increasing the sense that an interested public can participate knowledgeably in it and in democratic decision-making about it.
9) Technologically, *Project Galileo* will help demonstrate how advanced information technologies can improve the quality and character of educational opportunities attainable within our schools and colleges.

III: Plan of Operation

(a) The overall plan

Our plan of operation for *Project Galileo* has three main components. One centers on developing study support materials needed to implement the pedagogical program of the project. A second will develop a program for preparing teachers from diverse schools to introduce the project in their classes. Both these lines of effort will converge in the third, a full-scale pilot test of *Project Galileo* in ten selected schools in New York City during the 1994-95 school year.

With both the development of materials and teacher preparation strategies, considerable prior work will have taken place by the time the grant period begins. Development of materials through the New Laboratory for Teaching and Learning began in the fall of 1991 and has gone through two full cycles of development and formative testing in the classroom at Dalton. Starting in September 1993, a third cycle will be initiated as part of the Dalton project. During the summer of 1992, these resources provided the focus for an eight-day workshop to train elementary and junior high school teachers in the Fundamentals of Science and the applications of new technologies in teaching astronomy. This workshop yielded invaluable experience that helps shape the teacher preparation program that we propose.

(b) Developing the materials for *Project Galileo*

Materials for *Project Galileo* cover eight topics:

1) Classical positional astronomy
2) The contents of the universe, the basic forces
3) Stars — The observational base of astrophysics
4) Stars — The theoretical base of astrophysics
5) Stars — Stellar evolution
6) Galaxies, the large-scale structure, cosmology
7) The solar system — Earth and planetary geology
8) The origin and evolution of life.

The first six topics have been designed and written, although they need more refinement. Some gaps need to be filled and in two cases some reorganization would improve the material. For each, the evaluation mechanisms that accompany the tasks need further development. About half of the seventh topic—the part dealing with the planets—is well along. The part dealing with the earth itself and the eighth topic on the origin and evolution of life, are still in the design phase and a major aspect of materials development will be to implement these designs.

Our plan of operation for the Federal support of *Project Galileo* calls for intensive work developing these topics during the Spring of 1994. Essentially, there will be four distinct lines of activity during this time, each of which will proceed under the management of the Principal Investigator, Malcolm Thompson (see below, p. 249).

1) The materials for the seventh and eighth topics need to be developed. This work will be assisted by Michael Rampino, a geologist and chairman of the Applied Science Department at NYU (see below, p. 250).
2) All the materials need to be worked through by an astronomer and analyzed for scientific accuracy and completeness. This work will be done by George McCook, an astronomer at the University of Villanova and chairman of the Astronomy and Astrophysics Department (see below, p. 250)
3) All the materials need to be gone over by an editor who will revise for clarity and uniformity of expression. An editor will be recruited for the project, starting in mid-December 1993.
4) The whole set of materials, as they are completed, checked, and edited, will need to

be integrated for easy, coherent use within a client/server school technology environment. Design of this computer-based integration of materials will be the responsibility of Robert McClintock, one of the Co-Directors of the Dalton Technology Plan and Director of the Institute for Learning Technologies at Teachers College, Columbia University (see below, p. 250).

These four strands of materials development will go through an initial cycle of completion during the 1993-94 school year with an especially high level of activity during the Spring of 1994. There will follow, as an essential part of the field testing during 1994-95, a second cycle of revision and improvement based on experience gathered from using the materials in diverse school settings.

(c) Selecting schools as implementation sites for *Project Galileo*

Selecting schools for the field testing of *Project Galileo* will take place during the Fall of 1993, before the formal start of the grant. Dr. Frank Moretti, Associate Headmaster of Dalton and Executive Director of the New Lab, and Malcolm Thompson will oversee the selection of field test sites. They have significant experience collaborating with public and private schools throughout New York City. Both have been involved in the past with the I-CM Project for teaching science with the Interactive-Colloquium Method that was funded by the Secretary of Education, the DeWitt Wallace-Readers Digest Fund, and the Helena Rubinstein Foundation and have worked collaboratively with diverse schools in the New York City Public School System. The New Laboratory for Teaching and Learning has also been the center for the Mayor's Partnership for Public and Private Schools for New York City.

An Advisory Board will, among other things, help the Project Director and New Laboratory staff select schools as implementation sites. The board will include the following, who have agreed to serve:

Anthony Alvarado	Superintendent of District Two in the New York City Public School System.
Naomi Barber	Director of the New Visions Schools for the Fund for Public Education.
Talbert Spence	Chairman of Education at the American Museum of Natural History.
Jack M. Wilson	Director of the Anderson Center for Innovation in Undergraduate Education, Rensselaer Polytechnic Institute.

In past collaborations, we have learned that schools should be selected close to the actual start of implementation at the site and that broad interest in the project within the school, in addition to support from the top authorities, is essential to achieve success. We will use a range of criteria for selecting potential partners, among them:

(1) The cultural diversity of the school itself will be a very significant criterion. Our

expectation is that the school must in some way represent the range of students in the New York Public School System and therefore to some extent the range of students in most urban settings.

(2) Whether or not a school has sufficient technical base without requiring extensive upgrade to sustain the project through classroom use.

(3) The level of faculty enthusiasm for projects of this type and their willingness to work for approximately five weeks in the summer before the actual implementation of the project in the school.

(4) The full support of the principal of the school and a clear indication that the principal understands that the new technologies can enhance learning in the direction of constructivist pedagogical principles.

(5) The central support of each school's district superintendent.

The final deadline for the selection of eight public schools, two from each of the five boroughs of New York, will be January 1st, 1994.

The calendar for the process of selection is as follows:

10/15/93: Using the Advisory Board and our own educational network, including Teachers College, and diverse public and private school collaborators, we will collect a series of recommendations of at least 30 schools that might meet the above mentioned criteria.

10/15/93
to 11/15/93: Senior staff members of the New Laboratory for Teaching and Learning will make school visits which will include a demonstration to the administration and faculty of the interested school of *Project Galileo* and an explanation of the educational principles involved as well as a clear indication of where *Project Galileo* can supplant in an effective way the traditional curriculum from their specific curriculum outline. The school visitors will also review school facilities and interview the teachers and administration in order to determine levels of interest. Those schools that are still interested after the visit will express that interest by formally applying for participation in the project by December 1st and that formal application should include support from the Board of Education for public schools and the Board of Trustees for private schools.

1/1/94: The project will make a commitment to ten schools, adding five schools on a waiting list, with the goal that there be at least two schools in each of the city's boroughs, eight public and two private.

d) Initiating the Teacher Preparation Program, Spring 1994

From the schools finally selected, teachers will be chosen, in consultation with their principals, to introduce *Project Galileo* in their science program. The criteria for selecting the teachers will be:

(1) diversity;

(2) motivation and interest;

(3) intellectual preparation for teaching an astronomy course through which students engage in participatory science study.

The calendar for selection process will be as follows:

12/15/93: Principals at each school applying to be field test sites should have recommended, as part of their application, four prospective teachers as candidates for introducing *Project Galileo* in their schools.

1/11/94 to 1/15/94: The recommended teachers from the schools chosen as field test sites will be invited to a series of open houses at the Dalton School to learn about *Project Galileo* and to see it in operation. They will be interviewed by the project director in conjunction with a team from the development group and a representative of the advisory group.

1/21/94: Two participating teachers, who will introduce *Project Galileo* to their schools, will be selected by the above group.

This timetable hastens the selection of the teachers because we expect to require them to do some independent preparatory work during the Spring of 1994. In selecting teachers, we do not expect to find prospects who already possess all the skills needed to manage *Project Galileo* well. We learned from experience with the summer 1992 workshop that two things are of paramount importance as prerequisites in running a workshop on how to work with students in a participatory science study environment such as *Project Galileo* — basic subject matter competence in astronomy and skill and confidence in using computers. If the workshop instructors must concentrate on imparting to participants the subject matter or fundamental computer skills, the participants cannot concentrate well on the real matter, learning how to work with the new pedagogy. We want to select teachers early so that prior to the summer workshops they can, wherever appropriate, systematically develop through independent study or through courses their mastery of the subject matter and their skills with the technology. We have included in the budget a lump sum of $15,000 to help finance these preparations by participating teachers.

7/1/94 to 7/31/94: Summer training workshop will take place. Credit will be available for taking this workshop through Teachers College or in place of credit teachers taking this workshop will receive a $2,000 stipend.

The four weeks of the workshop will be allocated as follows:

Weeks 1 & 2: Basic training in the use of *Project Galileo* by working through sample topics and an introduction to the philosophical premises and the future of interactive networked multimedia.

Weeks 3 & 4: Each teacher, paired with a student, spends the mornings working on topics under the supervision of the summer training institute personnel, with afternoon debriefings for the teachers as a group discussing the educational possibilities and problems implicit in the materials.

(e) Design of assessment strategies for evaluating student achievement in the selected schools

In Section 6 below, we describe what we intend to do to evaluate the effectiveness of *Project Galileo* as an educational resource. The subject of evaluation there is the program we propose to develop. A significant element of the program to be developed consists of assessment strategies for documenting what students learn through *Project Galileo* and providing them helpful feedback that can help make their studies bear optimal fruit. Here the subject of assessment is the student.

Traditional assessments — quizzes and essays keyed to the text and the teacher's glosses to it—are not particularly relevant to understanding student performance with *Project Galileo*. Indeed, traditional assessments will be out of harmony with *Project Galileo* and would probably deflect students' effort into unproductive paths. We instead seek to develop three types of assessment strategies that are consistent with the goals and procedures of the program—embedded, portfolio, and transfer assessment.

Embedded assessment characterizes much real scholarly inquiry and problem-solving activity, especially as it is conducted by working groups. Embedded assessment opportunities will be integral components of the work-flow in the *Project Galileo* pedagogy. Once a week each class, should meet as a whole to present key findings, to explain preliminary hypotheses, and to discuss how to proceed. The whole process of inquiry moves forward as students share and criticize preliminary findings, searching out further information, developing and overturning possible hypotheses. All this is the embedded assessment integral to active inquiry and study.

Portfolio assessment results because students work together to solve a flow of specific tasks and problems in an environment where they can easily save their work and present it as part of their cumulative accomplishments. The portfolio assessment tools will allow students to preserve their accomplishments and will provide work that teachers can formally assess. The educational design of *Project Galileo* will include a set of guidelines for the formal assessment of these tasks.

Transfer assessment will involve the creation of special problem-solving challenges to be administered to groups that have completed *Project Galileo*. The theory here is that learning to learn is a most important achievement that can result from *Project Galileo*. A good way to assess whether this is happening would be to devise group problem-solving challenges that would show the degree to which students had internalized key strategies and capacities through their experience with *Project Galileo* and could transfer the use of them to the new setting.

(f) Supervision of the first pilot test in the selected schools and the formative evaluation of the test to ready *Project Galileo* for more general use

The full pilot test of *Project Galileo* will take place simultaneously at ten locations during the 1994-95 school year. The supervision of the actual pilot tests will involve visits by summer institute faculty, on-line communications through electronic mail and monthly colloquia at the Institute for Learning Technologies and the New Laboratory for Teaching and Learning focused on problems emerging in the process of implementation. The personnel conducting the supervision and training during the process of actual implementation will include Field Supervisors recruited for their expertise in astronomy and their understanding of participatory study strategies. Thomas de Zengotita, who has long worked closely with Malcolm Thompson in developing strategies for promoting scientific literacy, will be in charge of the teacher preparation efforts and will direct the Field Supervisors.

Through the process of supervision, formative evaluation information on the design and implementation of *Project Galileo* will be gathered and communicated to those in shaping materials development and teacher preparation provisions. The information will help in improving the selection of astronomical resources, in shaping the user-interface for working with them, for further developing explanatory materials, and perfecting the student assessment tools embedded in the project. In addition, experience with teachers at the implementation sites will be used to develop manuals and teacher guides further to help prepare the program for general distribution.

During the process of formative evaluation, the design of the student assessment tools will also be tested.

IV: Personnel

The key people in the project have extensive experience and excellent qualifications. Here are short biographies of the most important. Full resumes are in an appendix.

Principal Investigator
Project Direction

Malcolm H. Thompson, M.S., holds the Malcolm H. Thompson Science Chair at the Dalton School, where he teaches *Astronomy* and *Fundamentals of Scientific Inquiry*. He co-authored with Robert Jastrow, *Astronomy: Fundamentals and Frontiers*, a leading astronomy textbook used in introductory college astronomy courses. In

1989, with Thomas de Zengotita, he wrote a substantial report, "The New Scientific Literacy, which has led to changes in the way science is handled within general education for undergraduates at New York University. Since 1991, he has been working on the development of *Project Galileo* through the New Laboratory for Teaching and Learning at the Dalton School.

Geology and Earth Science Science Consultant

Michael Rampino, Ph.D., is Associate Professor and Chair of the Department of Applied Science at New York University. He is a Research Consultant at the NASA Goddard Institute for Space Studies and the Center for Global Habitability at Columbia University. His professional affiliations include the AAAS, the Geological Society of America, the New York Academy of Sciences, and the National Association of Geology Teachers, to name but a few. He has published widely in his field and is a frequent speaker at NYU and professional conferences and workshops.

Astronomy Consultant

George McCook, Ph.D., is Chairperson of the Astronomy and Astrophysics Department at Villanova University. He is a member of the PASP, AAAS, IAPAP, and Sigma Pi Sigma, the physics honor society. His extensive publications include *Small Telescope Astronomy and Undergraduate Research at Villanova University*; *CREATE, An ATIS Management Program*; *ATIS Management Software*; and *ATIS 93 and Its Impact on CREATE*. Research interests include variable stars, binary stars, data analysis software design, and astronomical education.

Technical Design

Robert McClintock, Ph.D., directs the Institute for Learning Technologies at Teachers College, Columbia University, where he is Professor of History and Education. McClintock helped to develop the Dalton Technology Plan and serves as one of its Co-Directors. From 1985-89 he chaired the Department of Communication, Computing, and Technology at Teachers College. He has published and lectured widely, here and abroad, on issues of technology and education and on the history of educational theory. His most recent book, *Power and Pedagogy: Transforming Education Through Information Technology* will be published late in 1993 by the Educational Technology Press.

Five: Budget Discussion

Much work pertaining to *Project Galileo* will be embedded in ongoing efforts by the New

Laboratory for Teaching and Learning, with the result that it will benefit from substantial cost-sharing. The New Laboratory for Teaching and Learning has already developed two versions of *Project Galileo*, with great success in the classroom. The new version will benefit from this experience and make it more ready for dissemination to schools throughout the nation. The Dalton Technology Plan is one of the most advanced efforts to integrate technology, K-12, in an excellent school and the experience and infrastructure of this effort will make *Project Galileo* far more cost-effective. Explanations of specifics in the budget will be found with the budget forms.

Six: Evaluation Plan

During the first year of *Project Galileo*, we plan to gather extensive data to serve as a base-line for evaluating the performance of the program in its pilot tests. We will document the achievements and cognitive skills of two groups thoroughly — those of the students who in the pilot year will work with *Project Galileo*, and those of the students who in the year prior take the courses which *Project Galileo* will replace in the pilot year. Information on the first group will provide a baseline for understanding the developmental effects of working with *Project Galileo*. Information on the second group will provide a base-line for comparing the achievements of those working with *Project Galileo* to those who have not.

In gathering data on the first group, we will lay a foundation for evaluating key expectations about the effects of participatory science study in courses such as *Project Galileo*. We would assess the full range of cognitive skills as measured against Bloom's taxonomy of cognitive skills. Here are some specific sorts of claims we would like to test, as these are the distinctive claims that indicate the unique and powerful value of the program.

- Students who have worked with *Project Galileo* will integrate factual information into explanatory arguments more often than students who have not.
- *Project Galileo* students will be more likely to extract and express principles from what they learn than other students.
- *Project Galileo* students will more frequently solve problems applying mathematical or other formal strategies.
- *Project Galileo* students will seek to use information resources available in their immediate environment to solve novel problems more frequently than other students.
- Given a problem, *Project Galileo* students will focus on it in conversation together more fully than other students will.
- *Project Galileo* students will more often mobilize teachers and texts, less as authoritative answers, and more as resources to help them construct or determine answers, than will other students.
- In writing or speaking about causal explanations, *Project Galileo* students will more often weigh multiple hypotheses, recognizing pros and cons for each, than will other students.

During the pilot test of the project, the evaluation team will refine the list of claims we seek to test and will gather base data for use evaluating these claims in subsequent years.

Seven: Institutional Resources

The Dalton School is a leading K-12 independent day school in Manhattan. A fact sheet on the school is included in the Appendices. The New Laboratory for Teaching and Learning is a research and development group based in the school that has carried out numerous innovative curriculum development projects. Since 1991, one of its major initiatives has centered on the Dalton Technology Plan, a effort to integrate networked multimedia resources throughout the school, K-12. This effort has been funded at the rate of one million dollars per year by the Phyllis and Robert Tishman Family Fund. The accomplishments of this work, with *Project Galileo* central among them, were featured as the harbinger of the school of the future in a one-hour video in the *Imagine* series, produced by Apple Computer, Inc., and released nationally in April 1993. For a complete description of the Dalton Technology Plan, see *Risk and Renewal: First Annual Report of the Phyllis and Robert Tishman Family Project in Technology and Education — 1991-1992* (New York: New Laboratory for Teaching and Learning, 1992). "Excerpts and Summaries" from this document are included in the Appendices.

[1] Robert Jastrow and Malcolm H. Thompson. *Astronomy: Fundamentals and Frontiers*. 4th edition, New York: John Wiley & Sons, Inc., 1984. 564 pp.

"Educating America for the 21st Century" — A Strategic Plan for Educational Leadership, 1993-2000: Robert McClintock and K.A. Taipale

The Institute for Learning Technologies, founded in 1986 at Teachers College, Columbia University, works to advance the role of computers and other information technologies in education and society.

Introduction

As we enter the 21st century, we embark on an era of historic change as sweeping as that engendered by the development of the printing press. The new communication, computing and information technologies have the potential to fundamentally transform education and society for the betterment of humankind.

The Institute for Learning Technologies is committed to advancing these changes by exerting educational leadership through innovative projects, seminal research, and enlightened counsel. It aims to nurture, in a sustained manner, the humane application of information technology in order to expand educational opportunity and achievement.

The Institute is pursuing a demanding vision — one that requires developing powerful tools, mobilizing many forces, and energizing large markets. The Institute believes that education can be changed profoundly for the better. However, it will not be changed through small efforts, backed by few resources, promising marginal results.

To achieve the cultural potentials of technology, educators need to step to the forefront of the effort, asserting leadership and taking responsibility for initiative. ***Educating America for the 21st Century*** begins such an effort. It sets forth a *program of practice* in which Teachers College and Columbia University can, and by tradition must, seize the opportunities presented by the flux of history to help shape a robust and humane information-based society in the 21st century. In such a society, information and knowledge, individuals and institutions and, more than ever, an enlightened citizenry will need to be intellectually empowered to provide for the common good.

Towards a Program of Practice

To educate America for the 21st century, a firm, astute agenda is needed. Established educational arrangements constitute a complex system of immense scale. They will not be changed with a bright innovation here or there. Innovations need to have systemic results — results that transform practice at all its levels — charting not correctives, but fundamental improvements in education at its very best. Here is the essence of the Institute's strategy for systemic change in education: use technology to enable educators to achieve the radical improvement of highly successful institutions.

Educating America for the 21st Century

Changes in information technology change what people can do in life. New technologies do not determine human fates; they alter the spectrum of potentialities within which people act. The new information technologies significantly affect the five matters that give information and ideas value in human activity — the production and reproduction of ideas; their storage; transmission; selection; and intelligent processing — thereby transforming the range of options within which people determine their lives.

In both work and leisure, people will increasingly find that success turns on using new forms of information and communication. Wealth creation as well as full social participation will require people to organize and use information, to create new knowledge, both personal and public. Hence, an education for the 21st century must provide people with mastery of the intellectual and technical skills necessary to participate to their full potential.

Technology facilitates many modes of collaborative interaction in working with ideas and information. Consequently, the Institute believes that both work and leisure in the 21st century will increasingly resemble idealized models of academic scholarship — they will be collaborative; focused on inquiry, innovation, and design; engaged in producing new knowledge, ideas, and experiences. If 20th century life was the era of *industrial* democracy, that of the 21st will be the era of *intellectual* democracy. The values inherent in the house of intellect will be central to the emerging commonweal.

Here is a worthy mission for educators, but to fulfill it, they too must master the possibilities of the new technologies. Formal education must adopt a new pedagogy, oriented not to text-bound subject matters, but to dynamic operational skills and collaborative modes of interdisciplinary thinking. Students will require new languages to interact with information systems — they will require a multimodal literacy involving sight and sound. Further, students will require a more refined ability to handle the language of inquiry, knowing where and how to formulate and frame their questions to obtain useful information and create empowering ideas. They will require the capacity to produce new knowledge by discovering, selecting, and combining previously unrelated data in novel ways. Education will increasingly be judged, not by what the educated know, but rather by what they are empowered to do in fulfilling their lives and contributing to the greater social good.

Schools — K-12, colleges and universities — will increasingly use methods that engage students in inquiry. Teachers will become intellectual coaches, engaging students as active participants in interactions with rich databases of networked multimedia information. Teaching through extrinsic manipulation or random reinforcement will give way to involving students meaningfully in task-oriented learning projects connected to their lifeexperience. Assessment will be through portfolios and performances rather than standardized tests and impersonal gradepoint averages. Such assessment will encourage performance mastery, more than test taking or laboring at set assignments.

Educational change is not, and should not be, technologically driven—but it is technologically enabled. Nor are the rationales for such change novel; rather, they are the fulfillment of the humanistic and progressive educational aspirations of recent centuries. These have been the aspirations of the enlightenment tradition and the Institute believes that Teachers College and Columbia University should and will be at the vanguard of this fulfillment.

Funding Requirements

The Institute seeks to achieve systemic change through three efforts at educational innovation:

(1) to implement, according to constructivist principles, real-world projects using multimedia and network technologies to create sophisticated learning environments;

(2) to sponsor research and critical inquiries that show how to make study at all levels more productive and meaningful, and

(3) to sustain public policy initiatives that mobilize broad coalitions of interested parties from academe, government and industry in order to transform education.

It is to these ends that the Institute has developed its program of practice for the period 1993 through 2000.

Historically, the Institute has proceeded on a project-by-project basis. It has sought, with a core operating budget of about $50,000 per year, to accomplish major initiatives. While it has had notable successes, its efforts to develop significant new projects, to disseminate technical expertise and applications, and to influence the policy debate have been ad hoc, lacking sustaining funds. Up to now, the Institute has used its available core resources to keep its technological base current and to commission a few special efforts.

Additionally, for the past two years, the Institute has been primarily occupied, in conjunction with the New Laboratory for Teaching and Learning at the Dalton School, with the successful implementation of the Cumulative Curriculum Project. This project, aimed at integrating networked multimedia technologies into the real life of a working school, is among the most advanced multimedia applications in the nation. (See *Ongoing Projects* for greater detail below.)

Neither leadership nor systemic change can be sustained on an ad hoc basis. Action commensurate with the opportunities at hand requires the Institute to expand both its programs and its funding substantially. In order to develop and implement practical applications of the new technologies; to achieve broad public dissemination of the expertise gained from implementing these applications; and to influence in a positive way the public policy debate, the Institute must develop its financial resources to the point where it can carry out its mission at a significantly heightened level of activity and sustainable independent of any individual project.

As a first step towards implementing its strategic plan, the Institute seeks immediate funding of $400,000 to meet its working capital requirements during the initial two-year period of expansion. Such funding will allow for a major increase in the level of proposal writing and project development activities by core staff members associated with the Institute as well as the initiation of a robust dissemination and policy effort. During the initial period of this plan, the Institute will expand its existing projects; develop and implement a number of significant new projects; seek additional endowment funding; and develop its educational consulting activities. Under the plan, the Institute will be essentially self-financing by the end of the second year, at a significantly heightened level of activity, through a combination of increased management income from externally funded projects, increased endowment income, and increased consulting income.

Throughout the plan period 1994-2000, the Institute intends to continue to increase the scale of its funding and its program. It will seek to expand its sustaining endowment from under $1 million to between $5 and $10 million. Concurrently, the Institute will continue to extend its existing projects, secure funding for new projects, and develop its educational consulting services. By the end of the plan period, the Institute intends to have an operating budget, independent of externally funded projects, of approximately $500,000 per year. Such a budget would support $250,000 in administrative and staff operations and $250,000 to invest in its technology and application infrastructure, preliminary project development, and substantial dissemination and policy development activity. Total externally funded project budgets at the end of this period, exclusive of the Cumulative Curriculum Project at the Dalton School, should be well in excess of $5 million per year. (See *Effecting Systemic Change* below.)

Through its work over the last seven years, the Institute has gained the experience and expertise necessary to exert significant positive influence over the development of education and the use of technology. In order to grasp the opportunity for leadership and excellence that exists, the Institute must expand its activities and funding significantly.

Programmatic Foundations

All of the Institute's current and future projects seek to produce change which will facilitate:

- Expanding the scope of educational attainment by making extensive cultural resources of high quality readily available through electronic means in ways that enable students and teachers in ordinary educational settings — K-12, colleges and universities — to manage them effectively and work with them beneficially;
- Making educative resources more productive by amplifying with artificial intelligence what the student can achieve unguided by teachers, so that teaching resources may be reserved for those crucial points where personal interventions can make a substantial difference; and
- Expanding the visual and auditory forms of knowledge so that they cease to be merely illustrative of knowledge stored and retrieved in written form and become instead full-fledged knowledge-bases with coherent, intelligent storage and retrieval systems, subject to direct access in response to the inquisitive play of curiosity.

In addition, the Institute seeks ways for schools, libraries, museums and other cultural institutions to extend their educative resources into the community and to make them available to the broadest possible audience through effective use of information technology.

Ongoing Projects

The Institute has built a base for a comprehensive, decisive effort. Several of the

Institute's current projects form the foundation for expanding its activities. These ongoing projects involve important underlying issues — integrating technology into the curriculum as a whole; developing the capacity to work, not simply with technological end-products, but through the processes of technological innovation; and providing open access to the use of information systems in daily life by those who lack social and cultural advantages. Here are three leading examples:

- **The Cumulative Curriculum Project**. Since 1990, the Institute and the New Laboratory for Teaching and Learning at the Dalton School have been collaborating on *The Cumulative Curriculum Project*, a major effort to integrate networked multimedia technologies into the curriculum and life of the Dalton School, kindergarten through high school. This project has three broad objectives:
  - To develop the infrastructure of equipment, software, and human skills needed to fully employ networked multimedia throughout the daily life of a working school;
  - To create collaborative, constructivist educational programs with the new technologies, helping students develop their cultural and human capacities more effectively than they would in traditional educational settings; and
  - To select from the marketplace hardware and software tools which can help teachers and students achieve a higher level of educational excellence and to integrate these into the educational infrastructure.

  The Cumulative Curriculum Project, as implemented through the Dalton Technology Plan, is among the most advanced comprehensive educational applications of networked multimedia in the nation, and is independently funded at $1 million per year through 1995 by the Phyllis and Robert Tishman Family Fund.

  The Institute believes that a new paradigm of educational design — the study support system — is emerging from the experience with the Dalton Technology Plan. Enabled by the new information technologies, yet firmly rooted in constructivist educational theory and principles, the study support system provides a rich, high-quality environment of educational resources that empowers teachers and students to take on new and liberating roles. Teachers become intellectual coaches, guiding and directing students; students become motivated learners, pursuing knowledge from a variety of sources previously unavailable to all but a few; learning itself becomes inquiry-centered and self-motivated. The study support system makes available for everyday use by teachers and students resources that were previously only available to scholars and researchers. Through the effective use of networked multimedia, these resources become available directly to the individual classroom and student. The educational design problem becomes one of finding the questions, situations, and scenarios that will engage students, and with them teachers, in exploring and constructing their understanding of themselves and their world through such resources. (See *Proof of Concept* below.)

- **The MENTOR Project**. The *Multimedia Educational Network Testbed ORganization* (MENTOR) is a joint consortium of the Institute for Learning Technologies, the Center for Telecommunications Research (the Columbia University center for advanced networking projects funded by the National Science Foundation and by industry) and Project Gateway (a Columbia University led coalition of engineering schools funded by the National Science Foundation). MENTOR seeks, through development, deployment, and practical usage, to investigate the appropriate networking infrastructure that will support the emerging digital educational and research requirements of the 21st century.

MENTOR will prototype applications that demonstrate the cultural value of very high-speed networks. MENTOR will link the consortium members' existing high-speed local area networks (LANs) through a fiber optic network using advanced protocols and switching techniques. It will provide interconnectivity to numerous digital information data banks located in major educational, cultural and scientific institutions, regionally and beyond. Current projects include deploying advanced multimedia servers and prototyping networks using asynchronous transfer mode (ATM) techniques for rapidly switching fast-moving data.

Through MENTOR, the Institute seeks to extend the Cumulative Curriculum Project to engage a wider range of schools in demonstrating the value of the study support system, and to enlist a variety of major holders of the nation's cultural resources — museums, libraries, and universities — in providing the collections needed to prototype comprehensive study support systems fully. The MENTOR project will serve as both a development prototype and as a working model for the high-speed multimedia educational and research networks of the emerging National Information Infrastructure. (See *A Driving Force* below.)

- **The New York Youth Network**. The *New York Youth Network* (NYYN) is an electronic bulletin board service for at-risk teenagers in New York City operated by the Institute and funded by NYNEX, the New York Community Trust, and the Robert Browne Foundation.

  Teenagers, most of whom have no other access to information technologies, use computers at a variety of community-based organizations in the metropolitan area to obtain information on jobs, health, nutrition, and other services through NYYN, to converse with counselors and adult role models, and to participate in peer discussions on topics from politics to poetry. The NYYN provides an initial foundation for efforts to broaden access to technology in education. The Institute must build upon the initial efforts of NYYN greatly to ensure that the educational use of technology meets essential standards of democratic equity. (See *Compelling Social Choices* below.)

These projects give concrete examples of the Institute's conceptual mission and provide a strong base from which to expand its activities. By developing intelligently designed local information environments, by linking them through high-speed network technologies to educational and cultural resource collections, and by making them available to the broadest spectrum of the community through schools, cultural institutions and technological means, such projects will serve as a national model and will help achieve an integrated, humane information infrastructure for the 21st century. The next steps in developing the Institute's program will build on these foundations by (1) extending networked multimedia approaches into other educational settings; (2) expanding the type and quality of networked resources available; and (3) ensuring equitable access to educational opportunities and cultural resource — all in a manner that encourages systemic change.

Tools of Dissemination

In addition to initiating innovative projects, the Institute needs to influence the process of political, educational, social, and economic development by insuring a broad distribution of its accumulated expertise; by helping to shape the public debate; and by participating in building the powerful coalitions that need to be mobilized to accomplish systemic change. Therefore, the Institute must undertake a significant, deliberate and sustainable plan of activities to effect these goals. These activities include: conducting directed research projects; commissioning and publishing findings and papers; sponsoring seminars, workshops and conferences; archiving and disseminating, by network and in multimedia format, databases of academic materials relating to education and educational technology; promoting public policy initiatives; and generally seeking to influence the development and integration of advanced information technologies into education and society.

- Conference and Seminars. The Institute is developing a program of conferences, seminars and workshops to be carried out as a part of its overall program. These meetings will bring senior decision makers from academe, government and industry together to forge alliances. By initiating high-level dialogue, the meetings will provide a forum for decisions that will shape the development of the emerging information infrastructure and education policies of the 21st century.

  The Institute has received a seed grant from the JHM Foundation to host a planning workshop for MENTOR to be held during the 1993-94 academic year. This workshop will set the stage for a series of conferences and seminars to be held under the general theme "MENTOR - Educating America for the 21st Century" and to be hosted in conjunction with several Columbia University entities over the next few years.

- Books and Articles. The Institute intends to commission various books, including collections of working papers and articles generated by its conference and seminar program, papers, articles and other writings for both academic and popular press publication. Also, the Institute is developing a newsletter to disseminate critical analyses of current developments, research results, and news relating to the educational uses of multimedia and network technologies.

- Electronic Publishing. In addition to making information available in traditional ways, the Institute is pursuing opportunities to use the new technologies themselves to achieve broad dissemination of important work and ideas about education and educational technology. Beyond publishing its own papers, articles and materials electronically, it will actively seek to help other groups disseminate their work as well.

  The Institute has begun development of ILTnet, an experimental Educational Resources Network, as a prototype for an education and educational technology resource for Columbia University to be accessible to students and the public through ColumbiaNet and the Internet.

Electronic *distribution* is not enough. To fulfill its potential, electronic publishing needs to address issues of editorial standards and intellectual influence. The public information servers maintained by Columbia University and Teachers College should become among the preeminent national electronic depositories for academic information on education, particularly for materials relating to the substantive use of information technologies in education and culture. To help attain such preeminence, the Institute will participate vigorously in efforts to achieve high standards of intellectual excellence in the emerging systems of electronic publication, while preserving open procedures of spontaneous access to them.

- **Educational Consulting, Design and Development Services.** As part of its efforts to exert influence widely and to disseminate the results of its work, the Institute will provide a variety of consulting, design, and development services to schools and educational institutions, cultural institutions, government entities, and corporate concerns relating to the use of advanced information and communications technologies in education and related markets.

  The Institute will provide technology planning advice, product and application development and assessment, and information and technology management advice to academic institutions — K-12, colleges, and universities — and to major cultural institutions. The Institute will also provide planning and public policy advice to federal, state and local government entities relating to applications of technology in education, cultural activities, libraries and other public information services.

  In addition, where appropriate to its mission, the Institute will provide consulting services to corporations in a variety of industries, including education, media, entertainment, publishing, computer, communications and others. As the level of activity through the Institute increases in accord with this strategic plan, it will implement a corporate affiliates program wherein participants would be entitled to certain nonexclusive technology transfers and exclusive consulting services in return for ongoing support of the Institute.

  In general, the Institute intends through its consulting services to further its primary purpose — to foster systemic change for the betterment of education and society through the humane application of information technology. These services will complement the Institute's ongoing activities and will provide further practical experience, as well as additional funding, for educational technology development. Also, these activities will enhance the Institute's ability to influence at the highest levels those institutions from academe, government and industry whose committed support will be required to achieve real change in education.

In addition to these activities, the Institute will continue to provide researchers, developers and students with well equipped facilities for working with the most advanced learning technologies.

A University Partnership

As an integral part of its program, the Institute is also committed to helping Teachers College and Columbia University integrate information technology into their own educational and research functions by applying the experiences gained through the Institute's ongoing projects to their requirements. In general, these efforts include:

- working with other Teachers College and Columbia University entities, including other institutes, centers, schools and departments, as well as individual faculty members, in developing specific proposals and implementing relevant projects,
- working with the college and university information service providers, such as the libraries, journals and presses, and academic computing service providers, to develop and prototype new digital services and products,
- working with the college and university administrations in developing an integrated approach to technological issues relating to educational settings, and
- providing researchers and others with an important and practical educational component to include in their own proposals and projects when seeking grants and other external funding.

In addition to specific projects, the Institute is working broadly with others in rethinking general education and the core curriculum, exploring ways to use information technologies to make these efforts more effective; in building connections between efforts of research scholars to advance the state of knowledge and the educational experiences of students in schools and colleges; and, in developing high-quality digital resources and educational tools for use by students and scholars. (See *Institutional Leverage* below.)

Effecting Systemic Change

Effecting systemic change in education will require the sustained application of diverse resources in a deliberate manner, according to a clear and rational plan. It is to help lay the groundwork for such an effort that the Institute has designed its program of practice. The Institute believes that there are four distinct requirements to effecting systemic educational change. These are:

- a *proof of concept*, to show that a significant alternative to existing practices is possible;
- a *driving force*, to provide the historical energy to carry innovations through to full implementation;
- *compelling social choices*, to legitimate the troubles and costs incurred with change;
- *institutional leverage*, to enable new practices to alter resistant institutional structures, transforming them from within.

The Institute has developed its program to meet these requirements and to provide a framework for the mobilization of disparate elements in a common endeavor.

<u>A Proof of Concept</u>

Many activities associated with the Institute seek to demonstrate that educational use of networked multimedia can greatly shorten the intellectual distance separating the frontiers of research, professional practice, and creative artistry from the introductory processes by which people, especially the young, construct their understanding of their culture.

Much of the work of the Cumulative Curriculum Project at the Dalton School aims to show that students can develop their understanding of a field by working with research and scholarly materials that have been configured for digital access. For example, through *Archaeotype*, groups of students work as a team to excavate sites representing ancient Greek and Assyrian cultures and they construct their understanding of these by working as archaeologists to make sense of the jumble of artifacts they uncover. Through *Project Galileo*, students, primarily humanities majors, work as astronomers with analytical tools of the field to interpret a wide range of research findings that they access through computers. In *Ecotype*, students are introduced to the earth and life sciences by uncovering rocks and fossils via computer and having to use the apparatus of geology and paleontology to make sense of their findings. Similarly, in English, Latin, and History courses, students are developing multimedia archives for the comparative study of events, texts, and performances in ways that require their using the full interpretative apparatus of scholarship and criticism.

In schools now, the reigning paradigm of instruction is that based on the textbook as an abridgment of subject matter that students should in unison master, subject by subject and grade by grade. As discussed above, the Institute believes that this paradigm will be challenged by the paradigm emerging from the Dalton experience — the study support system — where students construct their understanding of a field by working in small groups, with advanced tools and resources, surrounded by rich databases of networked multimedia information. The Institute is seeking to develop a proof of concept for this alternative paradigm of study and believes that there are significant opportunities for joint development projects between educational practitioners and a research university such as Columbia. A major role for the Institute during the coming years will be to nurture such joint efforts.

To fulfill this role, the Institute needs to develop significant projects in three overlapping, but distinct, areas: curriculum development, teacher education, and student assessment. To provide a full proof of concept for a new paradigm of education, the Institute needs to do much further work in each of these three areas.

- With respect to **curriculum development**, a strong project in a significant curricular area would last from three to five years at a cost of approximately $1 million per year. It would consist of three ongoing components — forming digital research resources, developing an educational prototype, and implementing its initial dissemination to cooperating schools. Through the work at the Dalton School, a significant start on such curriculum development work has been made, but a great deal needs to be done to complete the process, bringing it to the level where a full curriculum designed to take advantage of networked multimedia can be implemented in a variety of school settings.

  The Institute is working with colleagues at the Dalton School, Teachers College, and Columbia University to secure funding for a number of such curriculum projects, each on the order of approximately $1 million per year, aiming to initiate, in each year of its program, one or two such efforts within broad fields of the sciences and humanities.

- Historically, many good educational ideas have proved impracticable because teachers could not learn to implement them. A full proof of concept requires developing a good program of **teacher education**. With the emerging paradigm, teachers will need to be able to do two important things — they will need to be able to work confidently with the data and tools of their subject fields and they will need to manage novices helpfully as they begin working with those same resources. The Institute has helped initiate on a very small scale an initial internship program designed to prepare new teachers for such work.

  The Institute is seeking substantial funding to work in collaboration with initial school sites, including the Dalton School, with Teachers College and other schools of education, and with Columbia University, to develop a model of teacher education that combines advanced academic work with substantive apprenticeship in working schools using networked multimedia to enable education activity.

- New forms of **student assessment** are essential elements in a new educational paradigm. Under the old paradigm, students learn from textbook compilations of knowledge that have discernible contents of facts and skills which have been artificially segmented, limited and made discrete; and what the ideal student should know at any point is predictable. Student assessment then consists of measuring how far real students deviate from such norms.

  With the new paradigm, in which students work in and through the full apparatus of a field, not simply an epitome of it, predicting what the ideal student should know is nearly impossible. Student assessment then needs to shift focus, testing what actual students can do and identifying how fully they have mastered the skills of inquiry and practice in various fields. Through controlled studies at the Dalton School, the Institute has begun to develop new assessment tools that function in this way.

  The Institute will seek funding from the National Science Foundation and other sources for a major effort to develop new assessment procedures and to show that these are the appropriate ones to use in education settings that make full use of networked multimedia.

If the Institute successfully implements its planned initiatives in these areas, external project funding in the area of curriculum development should be about $1 million for the 1994-95 year, growing to between $4 and $5 million per year by 1999-2000. Funded projects in the area of teacher education should begin at about $500,000 for 1994-95 year, growing to about $1 million per year by 1999-2000. Goals for funding of student assessment work would be $1 million for 1994-95, growing to approximately $2 million per year by 1999-2000.

A Driving Force

Technological innovation is an essential enabling factor in the educational developments the Institute seeks to promote; however, it is hard to draw strength in a sustained way from technological change alone. Too often educators adopt a new technology as if it were a stable foundation for their novel efforts; what starts as an energizing empowerment becomes all-too-quickly an impediment of installed obsolescence.

Educational change that draws power from new technologies needs to do so by engaging in the process of technological innovation, not simply by acquiring its products. A significant element of the Institute's program consists of efforts to integrate its activities into the very processes of technological innovation so that, over time, the processes themselves become imbued with a substantial dynamism towards educational reform.

In order to engage the process of technical change, the Institute has been developing working alliances with research and development efforts throughout Columbia University and in other universities and technology companies. To do this well, it is important to nurture a set of reciprocal advantages through which these collaborations can mobilize as many resources to sustain the common effort as possible. To succeed, the Institute needs to become a valued, productive asset in comprehensive efforts to create and implement new technologies.

Advanced technology development in the area of networked multimedia is leading towards a high-speed wide-area information infrastructure. This infrastructure will digitally transmit intellectual resources, expressed through multiple media, from numerous sources to numerous destinations, and allow people to use these resources, through numerous different devices, for a panoply of different purposes. Education will be a very significant use of this infrastructure — this can be predicted. How students and teachers will use this infrastructure, however, is not something that can be dependably predicted at the outset.

Just as educators cannot simply install technological products, expecting them to remain indefinitely useful, so technologists cannot simply build a functioning infrastructure, expecting users to adapt to its characteristics, whatever these happened to be for reasons of technical convenience. There is a chicken and egg problem here that can only be solved by binding systems design and applications design in a tight, iterative reciprocity. Some educators need to be willing to work within the process of innovation, developing prototype applications in close collaboration with those developing prototypes of the enabling infrastructure. The Institute intends to fulfill this role.

As a result, the Institute must be highly collaborative in much of its work and in many of its project proposals. Currently, the Institute has three main foci for such collaboration, the New Laboratory at the Dalton School, the Center for Telecommunications Research at Columbia University, and the University's High Performance Computing and Communications Group.

- Collaborations with the New Lab primarily involve technology transfers, relatively short-term, ad hoc arrangements with companies — Apple, Archive New Media, Avid, IBM, NYNEX, Silicon Graphics, and so on — and with universities — Cornell, MIT, Syracuse — to explore the educational usefulness of new hardware and software. Such collaborations help keep the Institute's equipment environment dynamic, but they often have monetary and personnel costs that need to be defrayed from other sources. Hence, the Institute needs to plan for general equipment related expenditures on the order of $100,000 annually to maintain the Institute's readiness to receive and benefit from such technology transfers.

- Collaborations with the Center for Telecommunications Research are largely grouped around Project MENTOR, the Multimedia Educational Network Testbed ORganization, with the Institute serving as a standing resource for CTR, somewhat as if on retainer. CTR has the resources and expertise to advance high-speed networking projects and, in doing so, it can draw on the Institute and its spectrum of activities as a source of test applications.

  Resources accrue to this process from two directions. First, CTR includes the Institute in its fund-raising, either directly or indirectly, helping to get equipment and technical support that the Institute needs in order to work effectively in the technical environment that CTR is creating. (If CTR succeeds in its bid for renewal of long-term funding from NSF, the annual value to ILT of such support through Project MENTOR should be on the order of $200,000.) Second, CTR acts as a steppingstone by which the Institute enters into secondary collaborations with other participants in some of CTR's projects. (For instance, with help from NYNEX, the Institute and the Syracuse University School of Education are jointly seeking $600,000 from New York State for a Remote Education Project that would make use of the experimental NYnet, which CTR has helped initiate.) Over time, such secondary collaborations should produce approximately $500,000 per year.

- Collaborations through the Columbia University High Performance Computing and Communications Group may prove very productive. This is a group, convened by the Vice Provost for Research and drawn from across the parts of the University, charged with shaping the University's activities with respect to the emerging National Information Infrastructure.

  For the remainder of this decade, and on well through the next, large amounts of Federal resources will become available to develop the public service components of high-speed digital networks—for ensuring public access, and developing applications support software, as well as applications for education, health care, libraries, and government information. Primary funding in these areas likely to be authorized by the National Information Infrastructure Act over the next five years will be on the order of $1.5 billion.

  Even larger amounts of secondary funding will come into focus as a result of the primary effort. For example, more and more of the work that the many agencies involved in the primary effort — the National Science Foundation, the Commerce Department, NASA, the Department of Energy, the National Institute of Standards and Technology, and so on — as well as others that are not formally involved — the Department of Education, the National Endowment for the Humanities — are doing will be shaped to take advantage of the national information infrastructure. Additionally, a large amount of corporate development funding will address opportunities defined by the emerging infrastructure, all amounting to a very considerable investment in information technology and its cultural uses to be made in coming years.

As a key part of its strategic plan, the Institute intends to pursue such opportunities with and through the University's HPCC Group. This represents a major shift of delineation for the Institute, which had until recently demarcated itself more narrowly as a Teachers College entity. Given the scale and character of the opportunities for working with technology in education, a narrow locus of initiative is shortsighted. Part of the Institute's program for the coming years is to work as a Universitywide group, cooperating with other University groups, to respond to very large funding opportunities with the intention of making Columbia University as a whole one of the two or three national centers of excellence for working with digital technologies in education. The HPCC Group should generate a steady flow of large proposals, some of which would be instances of proposals described elsewhere in this strategic plan, others of which would fall outside of it. In either case, the Institute intends to be a ready partner, for the opportunities are many-sided and they require a many-sided response and effort in order to succeed.

In all these ways, the Institute intends to participate over a sustained period in the processes of technological innovation; helping to harness the work of technological innovators to the service of important human purposes and gaining thereby long-term, dynamic access to enabling resources, both technical and financial.

Compelling Social Choices

Technology is a powerful tool of change. Because of that, those working with technology incur historical responsibilities to be activists with respect to the problems of their times. Technological change is not a beneficent machine that guides itself, able to cure social ills without people choosing to make an effort to do so. In the course of its work in education and technology, the Institute intends to address certain problems as ones that demand attention and effort as digital technologies become pervasive in education and culture. Among these are the issues of open access to the resources of a digital culture and of an education for long-range, democratic choice.

- **Open Access**. Problems with access to the educational system generally are being recapitulated in the development of the national information infrastructure. Powerful political and economic forces are proceeding on the assumption that there can develop a mass market for digital electronics and programming that will merge entertainment and education and that will empower the latter by forging a strong electronic connection between home and school.

  However, the strength of this connection will vary significantly according to socio-economic status—strong for the middle classes and weak or nonexistent for the impoverished. In order to avoid exacerbating inequities in our society through these developments, ways need to be found to make Community-Based Organizations (CBOs) crucial access points to the national information infrastructure for the many young people for whom the home will not be, for reasons of economic and social stress, effective in providing such access.

  The Institute intends to work with CBOs in New York City and State to expand its New

York Youth Network into a model of how to provide effective, open access to advanced technologies for the underprivileged. In part, the task requires mobilizing resources to help CBOs and other groups acquire high-quality network access and workstations and to deploy them in ways that serve the disadvantaged well. But the task involves much more than technology, more than deploying networks and workstations; it entails creating new, more effective services, ones that can develop strong roots in diverse, multicultural communities, and that can provide real means for participating in the benefits of our common culture.

In its effort to accomplish such goals, the Institute will concentrate on developing the capacity of NYYN to help at-risk youths prepare both for sustained, prosperous employment in an economy that increasingly requires people to transform and renew their productive skills repeatedly through life, and for successful completion of advanced educational opportunities leading to careers in the knowledge professions. To achieve such purposes, funding for NYYN will need to expand from well under $100,000 per year to something on the order of $1 million annually.

- **Long-ranged, Democratic Choice**. With the rise of industrialism and the spread of advanced techniques in economics, medicine, law, and government, much of life has been stabilized and rendered relatively predictable. That has not, however, banished risk and uncertainty, but rendered them more abstract, more global, and more long-ranged. With these transformations, problems of public choice change significantly. Accountability, which could once be handled well through elections every few years within localities, regions, and nation-states, now becomes a global, intergenerational problem, turning often on obtusely abstract relationships, visible — if visible at all — only through very sophisticated statistical analyses and projections.

  There is a deep educational task embedded in these developments that will require sustained creative reflection by people engaged in emerging new conditions. The Institute intends to promote reflective inquiry into the political forms and procedures that may suit the emerging global network of digital communications. The Institute will re-examine the fundamental ideas of our democratic traditions — right, justice, duty, liberty, equality, happiness — and give a refreshed articulation of them as new technologies transform the scale, scope, character, and intensity of communications.

  For these purposes, the Institute needs to raise substantial funding, not to support emerging practice with the new technologies, but to support reflection back upon those practices, informing the work of those shaping new practices with a critical, examined vision. Currently, the Institute's endowment, beneficent relative to the means of its donor, is too small, relative to the scope and depth of these questions, to support the reflective work that they merit. Consequently, as part of its plan, the Institute will seek to expand its endowment from under $1 million to at least $5 million. In addition, the Institute will seek funding from the National Endowment for the Humanities and from various foundations for a set of projects devoted in a disinterested, pensive way to clarifying the ethical and political ideas that may be needed to chart a prudent course into the digital future.

Institutions seeking to influence change incur historical responsibility for the consequences of their actions. The Institute intends for its efforts and those of Teachers College and Columbia University to stand the test of time as a national model for an effective information-based society, one that people will experience as both empowering and equitable.

Institutional Leverage

Institutional leverage is an important element in the dynamics of innovating in education. To move new possibilities from potentiality to actuality, educators need to develop powerful leverage on working institutions. Schools and colleges are remarkably resistant to change. One can demonstrate the power of new practices; one can link them with material forces restructuring the practical use of information and ideas; one can imbue them with a compelling sense of public purpose; but without gaining institutional leverage on the educational system, the effort will remain peripheral.

Institutional leverage must be substantive; it must comprise significant changes in specific, active institutions and experiential realities in the life and work of individual students and teachers, parents and administrators. In addition, change must be implemented so that it becomes contagious, spreading infectiously from school to school, from college to college, from level to level, from locality to locality. When that happens for a sustained period, systemic change will result.

A significant component of the Institute's program is aimed at achieving institutional leverage in order to implement progressive education with networked multimedia. Among the key features are these:

- *Well-leveraged innovations must affect both K-12 and higher education.* A significant flaw in most reform efforts arises from separating K-12 schooling from higher education.
- Innovators will find the fulcrum for institutional leverage in the transition from secondary school to college. Changes in colleges, enabled by technology, will create institutional pressures for changes in secondary schools; and changes in secondary schools, enabled by technology, will send to colleges students with new skills and expectations, creating further pressures for changes in higher education.
- An important way to lever the college entrance process is to work on both extremes of preparatory education, that for the privileged and that for those at-risk. The Institute intends to show that:

  a. in elite private education enlightened use of technology will prepare students more effectively for admission and successful study at the best colleges and universities, and

  b. community-based educational networks can provide at-risk youths with effective ways to prepare themselves for entry into higher education.
- *Within K-12 education, the place to grasp the lever is the middle school.* Education there is substantive, but not yet clamped in the vise of testing. Good curriculum design for the middle school can develop students with far more active study skills, and these students

can force high schools to adapt and open themselves to innovation, particularly in institutions preparing students for elite colleges, as these institutions cannot afford to ignore what their best students can accomplish.

- Within higher education, the place to grasp the lever is the research mission of the university, which has been woefully estranged from its educational mission. As the tools and data of empirical inquiry come to exist increasingly in digital formats, they will cease to be confined to the esoteric laboratory and can be made central to a newly structured education from the student's early years through maturity.

These points do not line up, point by point, as the rationale for any of the Institute's specific projects, proposal by proposal. Nevertheless, the range of the Institute's projects do cover each of these strategies for achieving institutional leverage.

Some projects, such as the Dalton School implementation of the Cumulative Curriculum Project and the New York Youth Network, have been discussed above. Many of the possibilities for institutional leverage outlined here are taking shape in the Dalton Technology Plan. It has developed considerable institutional leverage not only within the Dalton School, but through various school associations; the leverage is spreading as a number of other institutions are beginning to move in similar directions. The importance of the middle school as an agent of change in the high school has become evident from institutional experience at Dalton, as has the possibility of using the resources of research scholarship as the foundation for constructivist inquiry. Likewise, the New York Youth Network may contribute to the development of institutional leverage by helping new groups gain access to established institutions. Plans to expand and extend the NYYN will enable educators to use information technology to build new channels of access to higher education.

These projects, although very important, are not the whole of the Institute's efforts to develop institutional leverage in the reform of education. Two further emerging initiatives will be of great import. One aims at institutional leverage in the traditional college at its most traditional point — the core curriculum and general education. The other aims at making the educational use of research resources systematic by creating a Center for Empirical Education and using it to facilitate new practices, particularly practices that will widen effective access to advanced education in science and engineering.

- **General Education and the Core Curriculum**. What the middle school is to K-12, the core curriculum is to college. By introducing networked multimedia into the resources of general education, enhancing the quality of engagement that students enter into with their cultural traditions, educators will ineluctably restructure the whole of higher education. The Institute seeks to develop institutional leverage for the use of networked multimedia at Columbia University. For example, the Institute is working, in collaboration with the Art History Department and the Center for Telecommunications Research, to make the visual materials for the Art Humanities course available in high-quality digital form over ColumbiaNet. And, the Institute is joining with the School of Engineering to seek funding from NSF's Advanced Technological Education project for a new Engineering Humanities course, which will be designed as a potential addition to the college core curriculum. The Institute will also cooperate with the University's library and computer services to develop digital support resources for the Contemporary Civilization and Literature Humanities courses.

In all these efforts, the object is not to change the scope and character of the general education offerings, but rather to provide networked, digital resources that will augment the depth and intensity of the experience for students. Some preliminary resources are flowing to these efforts from corporations and from internal sources. The specific intention, as part of this strategic plan, is to secure several hundred thousand dollars for each of three projects: 1) digitizing and annotating classic texts with multimedia commentaries — by students, for students; 2) prototyping the Engineering Humanities course; and 3) digitizing and annotating a repository of images that will sustain the study of Western art and civilization. As the use of networked multimedia spreads through the core curriculum, first at Columbia University and then elsewhere, significant institutional leverage will build because all students take the core early in their studies and they will expect similar uses of information technology throughout their work thereafter.

- **The Columbia Center for Empirical Education.** Education for the 21st century requires a vision commensurate in scope with the emerging national information infrastructure. The Institute believes that this vision will take form through the practice of empirical education. Throughout the era of print, education has rarely been empirical, understanding empirical education as a process by which students master fields of inquiry and practice by using the data and tools of the different disciplines and professions to solve substantive problems and to answer challenging questions. Instead, education has been dogmatic and derivative, based on digests, authoritative at best. Even school laboratories are stylized simplifications having little resemblance to the working laboratories of the subjects they represent. Too often, the laboratory becomes a place where students try to go through the motions specified by an authoritative menu.

  Traditional limitations are changing. Nearly all the data acquired in working laboratories are fast becoming digitized, and moving rapidly across the Internet from lab to lab and researcher to researcher. More and more, scholars analyze and interpret all this material with computer-based tools, many of which are not difficult to use. The emerging information infrastructure can transport all these observations, measurements, collections, and models to virtually anyone anywhere, along with control over powerful tools of rendering, calculation, comparison, selection, organization, and expression.

  These are the developments making empirical education a general possibility. The Institute will help initiate a Universitywide Center for Empirical Education to shape and deploy these developments, particularly in ways that broaden access to advanced technological education. In this effort, institutional leverage will develop in many different places as the Center maps and mediates access to advanced collections for a growing number of individuals, schools, and colleges.

  To make empirical education work well, educators need two key elements: fast, flexible, easy access to advanced digital libraries of data and tools, and powerful challenges and questions that will activate curious minds. When educators put such challenges to students, the students in turn will engage themselves, individually and as groups, with the digital resources in the work of empirical inquiry and reflection. A significant part of the funding for the national information infrastructure can support such work. It is in this sense that the idea of empirical education is commensurate with the emerging information infrastructure. The more resources and activities pour into the information infrastructure, the more feasible and powerful empirical education can become. Columbia University can take leadership in shaping these developments.

Towards this end, the Institute plans to join in efforts to secure multiyear, multimillion dollar projects for developing digital libraries, user tools for navigating through and managing intellectual resources of unprecedented scope and depth, and powerful triggering scenarios that can serve as the entryways for young inquirers. During 1993-94, the Institute will participate through the HPCC Group in developing at least one such proposal for research and development with digital libraries. In addition, the Institute may take the lead, again through HPCC, in seeking support from NSF, through its competition to establish Regional Advanced Technological Education Centers (up to $1,200,000 per year for five years) for the Columbia Center for Empirical Education.

Through such efforts to develop institutional leverage — efforts to introduce information technology into general education and to use the information infrastructure to introduce empirical education at many levels of study — educators may soon cross a threshold in the use of information technology. Since the advent of the microcomputer the expectation has been high that new technologies would bring significant change in education. Whatever the expectations, systemic change does not happen quickly as a matter of historic reality. It builds slowly as the opportunities for changing everyday practice in its full particularity steadily develop in many working institutions. The time to realize these opportunities is at hand. Together, Teachers College and Columbia University must shape them, through the efforts of the Institute for Learning Technologies, in ways that renew and extend their traditions of leadership in education.

Summary: Commitment and Collaboration

This strategic plan sets an ambitious agenda for the Institute. It is well thought out, however, and it is a plan in proportion to the scale of action needed in order to make technology serve effectively in efforts to deepen and extend the potentialities of education. Moreover, it is a plan commensurate with the stature of Teachers College and of Columbia University.

To effect this plan, the Institute seeks resources for four broad purposes — for a proof of concept, for harnessing a driving force, for facing significant social choices, and for exerting substantial institutional leverage. Assuming funding of the plan, the functional summary of the Institute's overall budget in the fifth year would be approximately as follows:

General Operating Funds	
Core Staff	$250,000
Technological Infrastructure and Information Dissemination	$250,000
Proof of Concept	
Curriculum Development	$2,000,000
Teacher Education	$750,000
Student Assessment	$1,500,000
A Driving Force	
New Lab Technology Transfers	$100,000
Center for Telecommunications Research (primary)	$200,000
Center for Telecommunications Research (secondary)	$500,000
Compelling Social Choices	
Open Access	$600,000
Long-Range, Democratic Choice	$600,000
Institutional Leverage	
General Education and the Core Curriculum	$600,000
The Columbia Center for Empirical Education	$1,200,000
Total	$8,550,000

Such an effort would constitute a substantial but achievable expansion of the Institute's activities. Now is the time to begin that effort. Opportunely, considerable funding is beginning to flow towards investments in the educational uses of technology and the national information infrastructure. Through its work to date, the Institute is poised to act on these possibilities with effect. However, to grasp the opportunity for leadership and excellence, there are two essentials: a strong initial commitment and a spirit of expansive collaboration.

Commitment entails decisive action, a willingness to make the effort required to achieve results. The Institute cannot from its current resources, alone and by itself, make such a commitment on behalf of Teachers College and Columbia University. A commitment of resources to the effort of expansion at the beginning is essential. The Institute needs at least $400,000 over the first two years to sustain a core, full-time staff to implement the level of project development, proposal writing, and other activities that this strategic plan requires.

Collaboration follows from attention to the large, the ultimately important goal — the betterment of education and the quality of life. So long as the end in view requires a large vision, the many possible projects, groupings, and participants will naturally fit together in a shared effort. The Institute believes that to accomplish the large goal, it must create strong alliances throughout Teachers College, Columbia University, and the world of education in all its forms. To that end, the Institute has and will continue to pursue joint initiatives with other institutes, centers, academic departments, schools and information service providers within the University. The Institute invites participation on all levels from the greater Teachers College and Columbia University community, as well as from the community at large. Together let us act to achieve a vision in which all people can use information technology to enable themselves to fulfill their potentials and aspirations.