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AUTHOR Slattow, G., Ed.
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ABSTRACT

This report for the period January 1, 1972 to June 30, 1976 describes a program conducted to reach the following major objectives: (1) to develop, test, and operate a large geographically dispersed PLATO IV network; (2) to implement an educational program involving educational liaison, teacher/author training, curriculum planning, and materials development; (3) to carry out a two-year field test and demonstration; and (4) to develop plans and strategies and assist in a systematic evaluation of the educational effectiveness of the PLATO IV system. Chapter 1 gives a brief account of PLATO history, a summary of the program, and a discussion of the results and their implications. Chapter 2 describes the methods by which the PLATO Service Organization provides author training, liaison, documentation, and other services to a large user community. Chapter 3 provides evaluation of system reliability, performance, use, and educational effectiveness, and presents a detailed case study in elementary mathematics. The next two chapters describe experience in the use of PLATO in mathematics and reading in elementary schools. Chapter 6 describes the community colleges program project, which has introduced PLATO curricula in accountancy, biology, chemistry, English and mathematics. Chapters 7 and 8 describe the experience with PLATO in the teaching of physics and chemistry at the university level. The final chapter discusses the continuous development of systems software for PLATO. (Author/VT)

In the preparation of this report, pages 10 and 11 became interchanged. Page 11 should be read first.

FINAL REPORT

DEMONSTRATION OF THE PLATO IV COMPUTER-BASED EDUCATION SYSTEM

A report made under NSF Contract C-723
Computer-based Education Research Laboratory
PLATO PROJECT

January 1, 1972 -- June 30, 1976

March, 1977

Chapter 1 of this report was prepared by F. Propst and G. Slottow, Chapter 2 by W. Golden, Chapter 3 by A. Avner and J. Gilpin, Chapter 4 by R. Davis, Chapter 5 by P. Obertino, Chapter 6 by D. Alpert, P. Jordan, D. Pondy, R. Hubel, and L. DiBello, Chapter 7 by B. Sherwood Chapter 8 by S. Smith and Chapter 9 by B. Sherwood. G. Slottow served as editor with special help from F. Propst, S. Dugdale and P. Jordan. R. Lipschutz and W. Wilson provided the art work and most of the typing was performed by P. Mansell, S. Morgan, and S. Pellum.

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INTRODUCTION

From January 1972 until October 1976, the National Science Foundation provided partial support for a major expansion, implementation, and evaluation of the University of Illinois PLATO Computer-based Education System. The major objectives were:

1. Develop, test and operate a large geographically dispersed PLATO IV computer-based education network serving at least 500 student consoles at several educational institutions at university, community college and elementary levels.

2. Implement an educational program involving educational liaison (cooperative programs) with participating institutions, teacher/author training, curriculum planning and the development of curricular materials.

3. Carry out a two-year field test and demonstration with the PLATO IV system providing a substantial component of direct computer-based instruction at each institution.

4. In cooperation with a qualified external evaluation team, develop plans and strategies and assist in a systematic evaluation during the field test period of the educational effectiveness of the PLATO IV computer-based education system.

This final report describes the program conducted to reach these objectives.

The program was centered at the Computer-based Education Research Laboratories (CERL) at the University of Illinois, but much of the work was performed in associated departments in the University of Illinois, in other universities, in junior colleges, and in elementary schools. The report begins in Chapter 1 with a brief account of PLATO history, a summary of the program, and a discussion of results and their implications. Chapter 2 describes the methods by which the PLATO Service Organization provides author training, liaison, documentation, and other services to a large user community. Chapter 3 provides evaluation of system reliability, system performance, system use, and educational effectiveness. It presents, in detail, a case study in elementary mathematics. The next two chapters describe experience in the use of PLATO in elementary schools; Chapter 4 reports on elementary mathematics and Chapter 5 on elementary reading. Chapter 6 describes the community college program project which has introduced PLATO curricula in accountancy, biology, chemistry, english, and mathematics in five community colleges. Chapter 7 describes the experience with PLATO in the teaching of physics at the university level. Chapter 8 does the same for chemistry. Finally, Chapter 9 discusses the continuous development of systems software for PLATO.

A separate report is being prepared by the Educational Testing Service (ETS), the external evaluator.

1.1 BACKGROUND

PLATO began in 1960 with a single terminal improvised from a used black and white television set, a storage tube memory and a single keyset designed and built in the laboratory. This terminal was connected to the Illiac, an early vacuum tube digital computer, through interface circuitry that was inherited from an earlier research program. The concept, still valid, was that the student would talk to the computer through use of the keyboard, the computer would talk to the student by writing messages, alphanumeric or graphic, on a display surface (the TV screen), and the software would be designed so that the dialogue would be meaningful, and so that it could be highly interactive. More precisely, the computer wrote the message on the storage tube from which it was scanned at TV rates for display on the face of the CRT. Or, alternatively a flying spot scanner transferred the image from a photographic transparency to the storage tube. The two kinds of images could be merged on the TV display.

The following year (1961) the system capacity was doubled to two terminals, and to distinguish it from the original, the expanded system was called PLATO II. This early version of PLATO was actually used for teaching on a small scale, and, in fact, college credit was given for the first time to students who took a course using PLATO.

Development based on this experience led in late 1963 to PLATO III which by March 1966 reached its maximum of twenty terminals operating on-line simultaneously. (There were actually 70 terminals scattered in other University departments, in a grade school and in a hospital, but only 20 could be used at one time.) PLATO III was essentially a well engineered version of PLATO II in which the image from any one of 122 transparencies (loaded at any given time) could be selected by the computer. Furthermore, this version of PLATO was interfaced directly to a more modern computer, the CDC 1604. With the storage tubes at the central computer and wide band video links from memory to display, this system did not lend itself to greater expansion, but clusters of 12 to 20 terminals allowed scheduling of entire classes. More teachers were motivated to prepare material for PLATO and by 1970, four years later, usage reached 100,000 terminal hours.

During ten years of productive use, teachers and staff educated themselves in the use, potential, and problems of this new medium. A new language, TUTOR, was invented to provide scope and flexibility in preparing courseware, and, at the same time, to simplify the authoring procedures. The kinds and amounts of computer processing required for interactive use of graphic displays became better understood, and a basis for the design of a truly expandable system was prepared.

The anticipated requirements of this new system, PLATO IV, stimulated the invention of new hardware that included: the Plasma Display Panel (a flat panel display device that could double as a projection screen for images stored on microfiche), an advanced graphics terminal, a random access projection system for microfiche, a random access audio system for automatically selecting segments of speech or music under computer control, a touch entry device, a communications system to support terminals over standard telephone lines, television channels, or through microwave transmission, and interface equipment to handle the input/output requirements of thousands of terminals.

Industrial development, stimulated by early research at the University of Illinois, brought the Plasma Panel to the commercial stage in 1971. The other new devices were developed to the prototype stage at CERL by the same time and were becoming available from commercial manufacturers. Finally a computer, the CDC 6500, was available which, through a rapid block transfer rate of 600 million bits per second between main memory and extended core storage, could efficiently support a time sharing community of hundreds of users.

By the start of the NSF program in January 1972, the basic technology needed for the PLATO IV system was at hand, and ten terminals were connected to the system. Hardware research would, of course, be necessary to increase versatility and to decrease costs, but further new developments were not required to implement PLATO IV on the scale envisioned in the NSF program.

This was not quite true for software, Although the basic system was ready in 1971, it was expected (and proved to be correct) that systems software would continue to evolve as both the systems software staff, and the user community gained experience. Software development, therefore has been an important component of the program through its entire existence.

1.2 SUMMARY OF THE PROGRAM

From a beginning of ten terminals on PLATO IV in January 1972, the number has grown to about 950, with up to 500 active simultaneously. The sites are scattered across Continental United States; one terminal is in Sweden, and terminals have been connected for demonstration in the Soviet Union, Italy, Rumania, Venezuela, Sweden, France, Germany, and Iran. There are presently over 2,000 users of the system who prepare material for PLATO IV, and over 20,000 students are using the system. For the past two years system usage has exceeded one million terminal hours per year.

With this expansion, system reliability has remained high with more than 95% of total scheduled time available to users. Of apparently more concern to classroom teachers is the probability of a failure during a class hour, a figure that tests of user attitude indicate should be less than 0.8. Except when hardware changes have produced brief periods of relatively low reliability, this condition has usually been met.

During the expansion of PLATO IV the system has also met design standards which include an average response time, to key inputs, of about 0.2 seconds, and processor loads of about 2,000 instructions per second per terminal for students. Peak loads for a terminal may be much higher and are well tolerated by the system. These figures are meaningful, of course, only if the system is acceptable to users, and if it provides effective instruction. User acceptance has been generally enthusiastic and all available evidence indicates that the system is effective educationally.

To support this expansion, CERL has operated the PLATO Services Organization, a group that provides training for authors both through short courses held in the Laboratory, and through on-line lessons. It has also developed an on-line, comprehensive encyclopedia (AIDS) for PLATO and the TUTOR language.

In addition, it provides consulting services in which a user and a consultant converse on the system by typing messages which appear instantly at the bottom of the displays. To help in these consultations the consultant can, with user consent, view the user's display images on his own terminal. These services are widely used. For example, in 1975 AIDS was consulted more than 600,000 times, or on the average, once every 40 minutes for each author. This group also provides system documentation and performs the administrative tasks necessary in the operation of a large system.

When the development of new courses for PLATO is begun, the responsibility for curriculum and lesson design generally rests with the users. PSO and staff members of CERL are prepared to provide help and guidance. However, in order to implement the educational program of the NSF program, three groups were established within CERL, two to work with the elementary schools in mathematics and reading, and a third group to work in five subject areas with community colleges in Illinois. All groups developed and adapted instructional materials, and all maintained close liaison with classroom teachers and appropriate administrators.

The elementary mathematics group produced about 100 hours of instructional material for grades 4 through 6, enough to allow a child to work at a PLATO terminal one-half hour a day for a full school year. The lessons were divided into three "strands", fractions, whole numbers and graphs. These lessons proved to be effective and gained high acceptance with teachers and students. One problem encountered in this program was a restriction in the allotment of extended core storage (ECS) which, in the first year of the field test, restricted the number of lessons that could be available at one time. Expansion of ECS in 1975 from one million 60 bit words to two million words eliminated this problem.

The elementary reading group developed about 80 hours of instructional material and has provided about 17,000 hours of instruction to 1,225 kindergarten, first grade, remedial and educable mentally retarded students. These lessons make extensive use of the random access audio device and the microfiche projector. Acceptance of PLATO lessons as part of the daily instruction has been enthusiastic for both teachers and students.

This program encountered two problems. One stemmed from an early decision to use a relatively complicated computer management system (CMS) to select lesson sequences for students on the basis of on-line measures of student performance. Disparity between what a student had learned and what the computer thought he had learned, often led to inappropriate choices. Furthermore, the CMS structure allowed for little teacher intervention. At least in its present form, CMS has been replaced by a system which can be used by the teacher with greater ease and control. A second problem related to difficulties in early versions of the audio response unit, and in the production of magnetic disks for these units. Unreliability interfered with normal use, and cumbersome methods of producing disks impeded the development of lesson material. With further development these problems have now been resolved.

The community college program has been a large effort involving 175 teachers in five community colleges, their administrators, and the community college (CC) staff in CERL. From September 1974, until June 1976, over 21,000 students participated in the program, and received over 97,000 hours of instruction in about 400 lessons in five subjects (accounting, biology, chemistry, english, and mathematics).

Close liaison was maintained between the college teachers and the CERL staff, but the teachers had complete control of course selection, the times and the ways in which PLATO would be used. Teachers also participated in the review and in some cases in the preparation of lessons.

Response on the part of students, teachers, and administrators has been enthusiastic, and each community college is continuing the operation of the PLATO beyond the NSF grant period.

At the University of Illinois, the Physics and Chemistry Departments were among the earliest to explore the uses of PLATO in undergraduate teaching. With NSF support, each department acquired 30 terminals to form a PLATO IV classroom, and with these facilities introduced PLATO into the regular curriculum. In each case PLATO has become an effective and well accepted part of the teaching program.

In physics, about 100 hours of instructional material have been prepared and have been tested with several thousand students at the University of Illinois and at other colleges and universities. Student attitudes as measured by questionnaire have been positive, and student performance as measured by examinations have been statistically the same as student performance in non-PLATO versions of the same course, despite a decrease in formal class time. Course development has emphasized classical mechanics and modern physics with waves and optics, topics that are taught as part of a three semester sequence at Urbana. Usage reaches a peak in the Spring semester when from 250 to 300 students enroll in the PLATO version of the classical mechanics course.

In chemistry, over 50 hours of PLATO lessons have been developed for use in teaching general and organic chemistry. By the end of the NSF program about 1000 students were using PLATO for one to two hours per week.

Total usage in the 1975-76 academic year was over 50,000 terminal hours. The figures represent a saturation point for the 30 terminal classroom. More terminals are required to handle more students.

Throughout the entire four years of the NSF program the system software has evolved continuously. This has been true in part because of the suggestions and requests from a large, sophisticated, and articulate user community, and in part as a result of both the responsiveness and initiative of an increasingly experienced software staff. An important related factor is that users of the PLATO system can communicate with others so easily on the system itself; through notes, conversations and drawings. This continuous interaction has continuously stimulated additions to software which provide new features not previously available to the user. An example is the facility for creating alphanumeric and graphic images directly on the display screen through simple controls. The system produces not only the display, but also the corresponding source language program. Other changes or additions relate to system organization and even to the structure of the TUTOR language.

1.3 PROBLEMS

The problems which have been encountered in the program generally resulted from the sheer magnitude of the program itself. They include deadlines missed because of delays on the part of vendors, failure to make administrative decisions promptly, delays in development of equipment or software, tremendously strained resources, and other problems either within or outside the control of CERL. As a result, some participants have been disappointed or discouraged. On the other hand, when these delays have eventually been corrected, acceptance and enthusiasm have been almost universal.

Second, the existence of the external evaluation seriously discouraged or prevented efforts to conduct internal evaluation; to avoid imposing too greatly on students and teachers and to avoid possible interference with the external evaluation.

The third difficulty associated with the approach followed by NSF is principally due to the burden placed on the external evaluator. In particular, because of the developmental nature of the program, it is virtually impossible for an external evaluator to develop an adequate understanding of such a program to develop an evaluation design. Even if the required effort is expended to develop such an understanding and to prescribe meaningful evaluation objectives and approaches, it is likely that the nature of the program will have changed in the meantime, negating the value of the plans made. Only the organization operating the program can have any hope of being able to carry out an evaluation which can keep current with the program evolution. This is an extremely difficult task, even for the operating organization. In addition, the performance of the evaluation by the program itself would provide a greater likelihood and capability of using the evaluation data in the guidance of the program.

If the issue of objectivity is critical, with regard to the operation of an internal evaluation effort, it would seem that the provision of an external monitor of the evaluation could facilitate such objectivity.

In the present case, we feel that valuable data has been lost, effort has been wasted, and the program has failed to benefit from data which could have been very useful to the program. We strongly recommend that the method of internal evaluation suggested by the above be considered for future programs of this type.

The original cost objective for PLATO service (approximately $1.00 per contact hour in 1976 dollars) has not been met to date; however, substantial progress has been made in this direction (estimates of present costs are in the range of $2 to $4 per contact hour), and all signs indicate that the original objectives are obtainable. Research and development is presently underway in both industry and at the University to reduce costs of terminal equipment, computer equipment, and communications. The results of this development, combined with the cost reductions normally accomplished with experience (learning theory), should provide cost characteristics which will allow very broad distribution of the technology during the next decade.

Finally, a comment relative to a continuing problem faced in this program is perhaps warranted. Namely, the problem of evaluation. There is no question as to the importance of monitoring development programs of the present type. This monitoring should be incorporated both to determine the level of success or failure of the program as well as to provide guidance in the evolution of the program itself. The approach adopted by NSF in this program was to contract with an external agency for an evaluation having a substantial summative component.

This approach has three fundamental difficulties. First, the nature of the PLATO program during the period of this effort was highly developmental. This means that greatest emphasis should be placed on formative, rather than summative, evaluation. The emphasis on summative evaluation continually raises the question as to the appropriateness of providing the program with access to evaluation data, for fear that this data might be used to modify the program in an effort to improve performance. It is quite unfortunate that such a situation should exist during a period when the primary intent is to develop and make an initial demonstration of a system.

1.4 MAJOR ACCOMPLISHMENTS

The major activities of this program fall into seven categories:

1. System development
2. Hardware development
3. Software development
4. System implementation
5. Curriculum development
6. Applications research
7. Media development

The following is a summary of the major accomplishments according to these categories.

1.4.1 System Development

It is difficult to overemphasize the importance of the system concept in addressing a problem as complex as CBE (Computer-based Education). It is relatively easy to implement hardware, software, curricular materials, or instructional design strategies and fail to make significant progress towards the goal of the program. The entire system problem must be addressed. In the case of CBE the entire sequence, from the initial design of the instructional materials, to the translation of this design to code, to the presentation of materials to students, to the collection of evaluation data concerning this whole sequence, must be addressed as a single problem. In addition, overlaying this broad consideration is the problem of evolution. In particular, adequate power and flexibility must be incorporated in order to make modifications and improvements in response to experience gained in the application of the medium. Without this latter feature, a program can immediately run into a dead end, because of the discovery that some preconception is either misleading or totally in error.

Perhaps one of the most important contributions of the PLATO program is in this area of system development. An extremely powerful and flexible medium has been developed which addresses this full spectrum of issues. Lesson materials can be created with relative ease. The system provides powerful capabilities that aid in this process. Thousands of persons, untrained in instructional design or computer technology have successfully developed instructional materials. The interface with the student has proved to be effective and enthusiastically accepted. The data collection and analysis capabilities are broadly and effectively used. And, finally, a powerful evolutionary capability has been demonstrated. This latter is demonstrated through the rapidity of software and hardware development as well as the development of new instructional techniques and new applications and methods of utilization which has been and continues to be maintained in the program.

1.4.2 Hardware Development

The range of hardware developed prior to and during the operation of the present program is substantial. Most of this development took place outside of the NSF program, however, since this program has been essential to the guidance of this hardware development, it seems appropriate to summarize it here.

The implementation of the PLATO system has required the development of a new and unique display technology, the plasma display panel; a powerful, low-cost graphics display terminal; an interface system to distribute computer output and receive student/author input simultaneously from hundreds of terminals; a communications system to serve terminals locally distributed over either TV of twisted pair linkages and to serve terminals remotely distributed through standard telephone lines, TV, or microwave links; and a series of peripheral devices, including the random-access slide projector, the random-access audio device, the music synthesizer, the touch input system, hard-copy output units, and a variety of specialized instructional and research devices. Present developments include a low-cost replacement for core-based swapping memory, improved communications devices, intelligent terminals, portable terminals, and voice recognition and systhesis capabilities.

1.4.3 Software Development

The PLATO operating system and the TUTOR language represent major deviations from the mainstream of software development. Possibly as a result of this, these developments have often been critized and misunderstood by the computer science community. However, during the past one to two years, as the power and effectivnness of the system have been demonstrated, these developments have begun to receive more and more recognition for what we believe them to be--very novel and creative approaches which provide great insight and progress towards addressing the design of software for systems intended for use by people who are not knowledgeable in computer technology.

1.4.4 System Implementation

Once a system development, with the concomitant hardware, software, curriculum, etc. sub-developments, has reached a state of maturity to allow the initiation of the "applications research" phase, the issues of implementation must be squarely addressed. These issues include the development of commercial sources for equipment, the organization of support operations, including author training and consultation, maintenance, and the procurement and installation of communications systems, the development of working arrangments with participating institutions and the scheduling of these and a myriad of other activities to insure that functioning terminals appear in classrooms or instructional laboratories in synchronism with predetermined academic calendars. The initiation of such a program oriented towards the installation of hundreds of terminals in more than a hundred sites in the absence of prior experience with a program of this magnitude is not a trivial task. And, indeed, the present program certainly encountered a fair share of problems as a result. On the other hand, a system of over 900 terminals, at more than 140 sites, functioning with a reliability factor of more than 95%, providing more than a million contact hours per year in more than 140 subject areas, providing a variety of additional services, including communications features, research support, computational facilities, reference services, consultation, maintenance reporting and diagnostics; and evaluation data has been implemented and operates on an around the year around the clock basis.

1.4.5 Curriculum Development

The curriculum development programs which have operated during the period of the NSF contract have varied in approach from that of an individual author independently writing lesson materials to that of relatively large curriculum development groups. The output of these programs has been approximately 6000 hours of instructional material in more than 100 subject areas. The types of materials range from simple drill and practice lessons to complex student controlled simulations. The quality of the materials range from poor to superior, and each type of approach has resulted in materials over this range of quality. Thus, while it is clear that substantial additional work must be done in order to evolve curriculum development procedures to improve effectiveness and efficiency, we have demonstrated the system capability to operate under a variety of development models.

1.4.6 Applications Research

As has been indicated, a wide variety of applications of the system has been explored. These range from utilization of terminals in individual classrooms, in learning centers, in offices, and in "PLATO" classrooms. Many models of use have also been explored, ranging from courses taught essentially totally on PLATO, to partial substitution of PLATO sessions for classroom sessions, to assigned supplemental sessions, to optional use of PLATO in conjunction with normal classroom instruction. Again, varying degrees of success have been observed in each of these cases. The system capabilities are adequate to function under any of the models; however, this area of "applications research" is an area where a great deal of additional work must be done.

Thus, far, we have only begun to explore the nature and degree of instutional changes which should be investigated in an effort to optimally utlize the system in the accomplishment of the educational objectives of different educational institutions at the various levels of education. We have had relatively little opportunity thus far to accomplish such optimazation, and, in general, it has proved very difficult for established institutions to develop a good working perception of how this new medium relates to its problems. These issues need to be explored carefully, if the medium is to provide the benefit which has been qualitatively demonstrated in this program.

1.4.7 Media Development

Perhaps one of the most exciting and important aspects of the present program is one that was not anticipated at the inception of the program. Namely, the roots of a new medium, which is much broader than CAI or CBE, have been established. It is too early to attempt an accurate and complete characterization of this medium. Perhaps the best that can be done at this time is to describe it as a computer-based information/communications network (CICN). In addition to instruction, the PLATO system presently provides a broad set of services including:

1. Electronic mail, including text, graphics, and animation.
2. On-line communications, including text, graphics, and animation.
3. Entertainment, including games, musical presentations, simulation, etc.
4. Personal services, including medical, financial, psychological, and educational and career planning.
5. Research computation.
6. On-line research. Physical experiments are controlled by the PLATO terminal, and analyzed results are graphically displayed in real time. In addition educational and social research can be conducted on-line and in real time.
7. Data processing.
8. Information retrieval.

In 1976, the PLATO system at the University of Illinois was electronically linked to the Control Data PLATO system at Arden Hills, Minnesota. Through this link, any terminal on one system can operate on the other system, so that all of these services are available in a network. For example, electronic mail can be delivered from a terminal connected to the Urbana system (located say in San Diego) to a terminal connected to the CDC system (located perhaps in Baltimore). In addition, lesson materials, software, and data are transferred from one system to the other through this link.

It thus becomes possible to visualize a national network of PLATO systems providing these and other services to institutions and individuals. The impact of this new medium is difficult to estimate, but the potential for improving communications and access to information is immense. Properly applied, this potential can have profound social and economic benefit to the nation and to the world. The NSF program discussed in this report has brought computer-based education, and more generally computer-based information/communications networks, a large step closer to this vision of the future.

2. PLATO SERVICES ORGANIZATION

The PLATO Services Organization (PSO) was established in the Fall of 1973 to provide many of the services needed by users of the PLATO IV system. Among these were documentation of the system and language; assistance on evaluation questions; training of authors, instructors and other classes of users; allocation of scarce system recources; and general liaison with the user community. (Obviously, most of these services had existed in some form in the past, indeed throughout the PLATO III and early PLATO IV eras. For much of that time, William Golden was in charge of general liaison and resource allocation. Elisabeth Lyman kept records on the ownership of files and allocated the terminals controlled by CERL. R. A. Avner assisted users and CERL on matters of evaluation. A number of individuals provided training for new authors, and James Kraatz devoted most of his time to consultation with authors on questions concerning the TUTOR language. The creation of PSO was, therefore, a matter of expansion and coordination of these services rather than the initiation of them.)

By the time PSO was established, PLATO IV had already achieved a nationwide network of users. That fact, the relative inexperience of the users, and the unique capabilities of the PLATO system suggested that we concentrate on on-line procedures for training and consultation. Other nationwide computer systems existed, but these could generally assume that their users were familiar with the terminals and computer languages to be used. Such users need only be taught the peculiarities of the specific system, not the system in its entirety. Also, at most locations novice users could find experts who might help them. In the case of PLATO, our terminals were unusual and highly sophisticated. The language we used was generally unknown. Some of the functions, e.g., running classes included the setting up of routers, class rosters, data collection mechanisms, and the analysis of student data, have no analogs in typical computer usage. A great many of the users were complete novices who had never worked on a computer. Finally, the PLATO system, then as now, was undergoing rapid development which meant that even experienced users required frequent retraining. Thus, the entire PLATO community had to be trained from Urbana. These arguments had already produced elements of the "aids" system which was to become the most important part of our system documentation.

Originally, "aids" was to be a set of PLATO lessons that helped users understand the TUTOR language and simultaneously served as a reference manual for the experienced author who might forget details. Some of the lessons provided interactive training by which an author might practice the use of TUTOR commands before entering them into his own lesson. It has expanded into a rather complete encyclopedia of PLATO. The bulk of the contents is still related to details of the TUTOR language, but there are substantial portions of other aspects of PLATO: the use of PLATO, bibliographies of other sources of information, instructional design considerations, etc. The PSO author group has devoted more of its time to the writing and maintenance of "aids" than to any other project. Acceptance by the user community has been extremely gratifying. During the last complete calendar year for which statistics are available (1975), "aids" was used by authors more than 600,000 times which meant that on the average, each author consulted "aids" once in 40 minutes. The mean waiting time after an author made a request and before relevant information began to appear on his screen was 3 seconds. Current statistics (August 1976, a rather slow time of the year for PLATO) show 773.5 users per day requesting answers for 1900 questions. All parts of the "aids" encyclodedia have been completely rewritten several times. In addition to major rewrites in which whole chapters are reworked so as to better answer the questions we hear users asking, there are daily corrections to remove errors found by users and to keep it an accurate description of the ever-changing TUTOR language and PLATO system. We usually achieve our goal of making relevant changes to "aids" within 24 hours of the time the system programming staff announces new or changed capabilities.

What we have, then, is an encyclopedia of several thousands of pages (more than 100 separate PLATO lessons) organized into chapters, each of which provides both an overview for the interested reader and individual descriptions of TUTOR commands and system capabilities. Access to the correct description is available to an author in two ways. He may enter the "aids" lesson as he would any other lesson, read through the main index (chapter headings), choose a chapter, and then read through the appropriate sub-indexes until his questions are answered. Authors interested in overviews are best served this way. The author seeking fine details about some topic he believes he generally understands goes directly to the relevant information by entering a keyword or phrase. Typically, the sequence is the following: an author is working in the TUTOR editor; he presses the "Q" key and types a key word (even most misspellings will be recognized); in a few seconds he is looking at information relevant to his question. When his question has been answered, he presses the shifted BACK key and in one second or less is returned precisely to the place in his lesson where he was working. No printed documentation or network of human consultants could match "aids" for the provision of accurate and rapid author assistance day and night throughout the nationwide PLATO community.

One should not conclude that human consultants are unneeded. They are necessary. For PLATO, the same PSO group which writes and maintains "aids" serves as consultants to the user community. They perform that service from our offices in Urbana via the system itself. An on-line consultant service was implemented with the following features. At any time an author may press the TERM key and type the word "consult". The fact that someone needs assistance is transmitted to the terminals at which consultants are working. When he is free to do so, a consultant checks the list of people waiting for help and offers his service to one of them. During the consultation session, the consultant can see the contents of the screen of the consultee. The two of them can converse by typing one line at a time which appears at the bottom of both screens. Although we can only guarantee that consultants will be on duty during the normal working week, in fact there are usually consultants available most weekday evenings and often on weekends. Additional consultative help is provided voluntarily by some of the junior systems programming staff. Thus, authors find human help most of the time that they might need it. Clearly, in addition to serving the needs of the users, this service provides feedback to the consultants about those aspects of the system which are confusing to users and which need be better described in "aids". Although we have just begun to keep accurate statistics on the use of the consultation service, it is generally agreed that the rate of use is two to three dozen requests per day. That number does not include a substantial number of requests for help which come in by other "unofficial" means such as the system "talk option", the public telephone, or in person visits by authors. It also fails to include the one or two follow-up communications which many consultant calls require. Limited evidence indicates that authors typically wait about 8 minutes before receiving help from a consultant and that a typical consult interaction lasts for about 11 minutes. Again, that time does not include follow-up. Waits for service of much longer than the 8-minute average sometimes occur when all of the consulting staff are called to a meeting or early in the morning when none of the staff are likely to be present.

Because of their experience and skill in communicating ideas to users, the PSO staff has been asked to produce other forms of on-line assistance to users. They have written "help pages" available in the TUTOR editor and other system lessons. They also produce the text for error diagnoses seen by users when either a condense or execution error occurs. In these and all our efforts, we work very closely with the system programming staff.

The PLATO library of disk files numbers about 17,000. These are lessons, and a variety of data files. Elisabeth Lyman and her staff keep track of all those files, their creation, renaming, movement among the various disk packs, and destruction so as to assist authors who from time to time "lose" some of the space assigned to them. This effort is primarily a manual one and probably unacceptable as a permanent part of the PLATO system, but we have always provided the service. In the process, Mrs. Lyman's staff gains the knowledge needed to advise users about what curricula are available on PLATO. Until a functioning catalog of available lessons is provided on the system, that service is vital. When such a catalog is available, the same staff will maintain the catalog. In recent months, we have begun to offer lessons for commercial publication. It seemed natural that Mrs. Lyman's knowledgeable staff handle the many and detailed communications between publisher and authors.

Still another function of the PSO staff concerns the training of beginning authors and upgrading of the training of authors. Ideally, this too would be performed via the system; and the series of lessons entitled "introtutor" provides a limited capability along that line. However, we have repeatedly demonstrated that concentrated training by skilled instructors pays off. We recommend that new authors come to Urbana for at least a week and preferably several weeks if they are going to enter a serious lesson development project. Lack of foresight, time, and travel money prevent most authors from taking advantage of our otherwise free training services. Nevertheless, there have been enough students to permit us to develop a rather effective beginning training program. It deals mostly with elements of the TUTOR language and the use of the PLATO terminal. More needs to be added about effective use of PLATO in ongoing instruction and questions of efficient instructional design. The staff of consultants also provides this training.

Memory allocation, both for magnetic disks and for the extended core storage (ECS) that holds the records for on-line users, is another responsibility of PSO. Originally, PSO actually created the individual files requested by all the various authors. Now that is done for only a minority of authors. Our major responsibility is limited to the bulk distribution of disk space on a monthly or less frequent basis. Similarly, the allocation of ECS has been reduced to an almost automatic per-terminal allotment.

Over the years, CERL had received some unfavorable criticism about the volume of information concerning PLATO available in print. PSO also has the responsibility to stimulate production of hard copy documentation of the PLATO software system, the TUTOR language, educational experiments using PLATO, hardware inventions, etc. We did not have the resources to employ a number of professional technical writers. We could provide editorial assistance and constant reminders to the researchers that documentation is vital. To a considerable extent, those two factors did succeed in stimulating the production of hard-copy documentation. Some documents were produced without any assistance from PSO. Many received at least editorial attention from PSO, and a few were produced entirely by PSO staff. Among the publications in the third category is the series entitled PLATO Report to Users. This is an occasional publication sent to administrators in charge of the more than 100 PLATO sites. It discusses policy questions and recent or upcoming major changes in the ways PLATO functions. We found it necessary to produce this series since there is a small but very important minority of people who direct PLATO activities at various sites and who do not themselves use PLATO terminals on a daily basis.

In summary, the PLATO Services Organization has succeeded in developing a rich variety of informational services for the many users of the PLATO system. Most of those services rely directly upon the unique instructional and communicative features of PLATO. All of the services, like the PLATO system itself, are under continual redevelopment as a result of feedback from our thousands of users. Users view PSO services as an integral part of the PLATO world. They appreciate them and rely upon them. They never hesitate to tell us when we fail, but they are also free with their praise.

3. INTERNAL EVALUATION

3.1 INTRODUCTION

All major groups within CERL are involved in some aspect of research and/or development. As a result, most collect and evaluate data which can contribute to a better understanding both of the current status of the PLATO system and of the effectiveness of alternative applications of the system. The PLATO Educational Evaluation and Research Group (PEER Group) serves as an in-house resource for this effort by supplementing the evaluation resources of individual groups and by performing applied educational research of general benefit to users of the PLATO system.

The major goal of PEER Group support of work under the NSF contract was in providing data for improvement of services. Efforts included measurement and documentation of system availability, monitoring of system acceptability by users, and aid in formative evaluation and instructional design to the various curricular groups. As will be detailed below, the latter function was limited both by the small number of qualified personnel available and a desire to insure that the Demonstration project not be a "hot-house" effort nurtured by professional support unavailable under normal conditions. Members of the group also provided direct support to the external evaluator, the Educational Testing Service (ETS), and its subcontractors where coordination or aid was required in collection of special evaluative information.

This section will summarize data which provide an indication of the degree of (1) system accessibility, (2) user acceptance, and (3) instructional effectiveness. A summary of evaluation problems encountered during the National Demonstration will complete the section.

3.2 SYSTEM ACCESSIBILITY

System accessibility is the basic requirement for effective implementation of CBE. It is determined by the degree to which (1) hardware is physically present, (2) system components function reliably, (3) the system performs within design specifications, and (4) these specifications permit useful instruction to be presented. Wherever possible, data on these factors have been collected by techniques intended to reduce reporting bias. Results have been reported to users in open files to permit a continual independent audit of accuracy and appropriateness. Personnel from NSF and ETS have additionally had access to systems data not normally provided to general users of the PLATO system.

3.2.1 Availability and Reliability

The first two aspects of accessability are summarized in Table 3.1. The data in Table 3.1 give a very conservative estimate of the reliability of a system in stable operation. For example, terminal availability data include down-time during night and weekend hours (even though maintenance service would not normally be expected at those hours) because terminal use is not limited to "office hours." Similarly, this down-time includes travel time to terminals that were over 1000 miles from Urbana and which were not a part of the Demonstration. Constant modifications in hardware and software

TABLE 3.1

PLATO SYSTEM AVAILABILITY

	1972	1973	1974	1975	1976
HARDWARE[a]					
Terminals					
purchased	200	304	801	921	950
in place	200	304	780	893	921
Audio Units	1	4	72	82	197
Touch Panels	0	31	111	655	717
USAGE[b]					
Thousands of terminal hours per year	138	348	676	1,105	1,189
Average hours per terminal per week	26.5	26.5	23.9	25.4	25.4
RELIABILITY[c]					
Central system mean hours to interruption		7.24	6.51	11.90	16.60
Mean hours of interruption		.10	.23	.34	.39
Probability of class hour interruption		.14	.15	.12	.10
Terminals-Mean weeks to maintenance		5.21	7.35	11.58	13.24
Mean hours down per month per terminal		7.6	13.6	10.2	9.6
Total System					
% Total hours terminal time usable		95.9	94.4	94.3	95.0

[a] Terminals "in place" were determined by phsical inventory. Not included were terminals in transit between sites, terminals being repaired, or terminals otherwise not actually in use.

(TABLE 3.1 Continued)

(TABLE 3.1 Continued)

[b] Usage prior to July 1974 was based on manual sampling at periodic intervals. After that date usage was based on a program which automatically recorded use of every terminal once each hour.

[c] Central system reliability based on automatic recording routine. Terminal reliability based on data base attached to on-line repair request program. Note the increase in mean hours of interruption for the central system in recent years. This effect is due to elimination of minor problems from the mix of system problems. What remains are largely hardware difficulties which occur upon installation of new equipment and which typically require more time for solution.

were also being made (and tested) during the period covered. A commercial installation which uses only tested versions of software produced by this system currently shows reliability figures approximately twice as good as those shown here. The software section of this report indicates the benefits and justification for continued modification of an operating system. Very briefly, the modifications being made at this time are of a nature that go beyond the present state-of-the art. Hence, complete evaluation requires that they be tested under conditions of full system load or within the context of an actual instructional situation. Naturally, preliminary testing is always done during non-prime time ("prime-time" consists of the hours from 7:40 a.m. to 10:00 p.m. Monday through Friday and 8:00 to 12:00 a.m. on Saturday--the time during which service of highest reliability is provided).

It will be noted that about 94 to 95% of total prime time has actually been available to users since 1973. This figure is unfortunately not an adequate indication of the quality of service provided to instructional users. Unlike many time-shared computer operations, instructional users are as severely affected by interruptions of service as by lost service. A better indicator of quality of CBE service is provided by knowing the probability of a class hour being interrupted. A study of new instructors indicated, for example, that knowing the percentage of scheduled time that their class was able to use PLATO accounted for only 21.8% of the variance in their attitudes toward system reliability while knowing the percentage of hours interrupted accounted for 62.4%. This study (which is being performed as a part of a contract with the Advanced Research Projects Agency of the Department of Defense) also indicates that instructors who experienced interruptions in less than about 8% of their classes perceived PLATO as sufficiently reliable for instructional use. Those who experienced higher rates of interruption generally perceived PLATO as being too unreliable for instructional use. Because hardware modifications often caused brief periods of very low reliability, the yearly averages reported for probabilities of class-hour interruption in the above table are well above the rates actually observed by most instructors. Thus, a group of 24 new instructors who used PLATO for a total of 822 class sessions contained only five who expressed a belief that PLATO was too unreliable. This was despite the fact their experience had been obtained during a period when two major additions of hardware had caused severe problems for over a two-month period. A group of 109 Community College instructors also saw system unreliability as a relatively unimportant factor in use of PLATO. Less than 6% felt that various aspects of system unreliability were a "major problem." The problem most often indicated as a "major problem" (by 15.6%) was the lack of enough terminals for all students who desired to use CBE.

3.2.2 Design Standards

The PLATO system depends on three major design factors. These have to do with permitting students to have rapid access to a specified quantity of computer and storage resources independent of system load. Specifically, in order to permit smooth operation without hesitations that might be interpreted by the student as a failure for a response to be accepted, response times for key inputs for students in lesson material are expected to be less than 0.2 second. Also, each student should be able to use materials that execute 2000 computer instructions per second and access disk storage an average of once each minute. Meeting these specifications is of little practical interest unless there is also evidence that useful student operation can be done at such levels of access to resources. Sampling of key echo times under a variety of system load conditions has indicated that attempts to make system service load-independent have been largely successful in this area. In general, it has been found that the probability is at least .99 that 99% of key echo times will fall below the statistical tolarance limit of 0.2 seconds regardless of system load if the student is using lesson material that is itself within design limits (i.e.--load independence is insured by limiting the load that any individual user can place on the entire system). To determine if these other design limits permit reasonable applications of CBE, records of all users of the PLATO system were examined in early December, 1976. Of the 27,731 records, 22,401 (80.8%) were for individual students and the balance were for authors, instructors, or for special multiple-student use (commonly used for demonstration or other non-instructional applications). The records summarized usage for periods of up to several years in some cases and included a total of over 1 million hours of terminal experience. Table 3.2 indicates centile points for total hours, TIPS (Thousands of Instructions Per Second), and DAPM (Disk Accesses Per Minute) for student and other records.

For students, 85.5% of records averaged less than 2 TIPS and 75% of records averaged less than 1 DAPM. Thus, the majority of student records appear to have been able to stay well within the design limits.

3.2.3 System Utility

Usage by individual students could also have been far higher for brief periods without degrading either system operations or their own operation

TABLE 3.2

USER DEMANDS ON SYSTEM RESOURCES

Centile	Hours Student	Hours Other	TIPS Student	TIPS Other	DAPM Student	DAPM Other
50	3.9	17	.75	2.31	.41	1.69
75	10.6	113	1.28	3.87	1.00	3.32
90	34.8	468	2.52	5.53	2.69	5.43
95	41.9	948	3.55	6.78	4.51	8.15

Note:

Entries for each centile listed indicate the upper bound for that quantity. For example, 75% of students had accumulated no more than 10.6 hours of system use.

since the peak usage of one student is likely to coincide with a period of low usage for other students when sufficiently large numbers of users share the same resource. That this is possible is suggested by the fact that some students and most other users actually averaged higher rates than the design levels (thus indicating that the resources were in fact available). In addition, contact with instructors of major courses indicated that there were seldom any indications of student operation being degraded as a result of excess demand on resources (users with author and instructor records could and did notice degraded service during peak usage since they had lower priority than students in accessing resources beyond the design limitations). Only one major curriculum area (computer science) consistently reported degraded student performance. In this case, very sophisticated materials which permitted students to simulate operations in a variety of computer languages made demands on system resources that were far beyond design specifications. Materials of similar levels of sophistication in the areas of chemistry and physics, however, showed demand levels that were well below the design levels. Thus, it appears that the design specifications of the PLATO system do permit useful instructional materials to be supported in a wide variety of subject-areas.

3.3 USER ACCEPTANCE

The second requirement for effective system implementation is the presence of user support. Special efforts were made throughout the Demonstration period to insure that students and instructors who used PLATO also served as expert sources of information for modifications of software and courseware. These efforts were primarily intended to insure that erroneous preconceptions of how CBE should be used would not dictate actual design. Secondary benefits of the approach included direct production of materials by members of the institutions and a general acceptence of PLATO as a tool for aiding instruction rather than as simply a technological gimmick. Individual descriptions of curricular projects found later in this report contain evidence of such widespread user acceptance. This information will not be repeated here. It will, however, be useful to consider some overall measures of acceptance. At the institutional level, the best evidence for acceptance is the fact that, despite severe financial restrictions, every community college which was part of the Demonstration has underwritten the major costs of continued use. At the elementary level, funding was simply not available despite continued interest by teachers and students. A restricted implementation (with equipment costs underwritten by the University of Illinois and the State of Illinois) does continue in the elementary schools. Tables 3.3 and 3.4 below indicate that the average rate of usage of terminals at these sites has remained essentially stable through this change in support. Since there are large individual differences among sites in the number of scheduled school days, the figures in these tables should not be used as an indication of terminal usage during class days.

TABLE 3.3

Community College Usage

Comparison of External and Local Support

	Total Terminals	Total Hours	Hours/Terminal
November 1975 (NSF Support)	118	11,092	94.0
November 1976 (local Support)	118	12,043	101.2

TABLE 3.4

Elementary School Usage

Comparison of External and Local Support

	Total Terminals	Total Hours	Hours/Terminal
November 1975 (NSF Support)	98	3,898	39.8
November 1976 (Univ. Support)	60	2,430	40.5

An opinion survey of 109 community college instructors who had used PLATO for at least one semester indicated generally enthusiastic attitudes. In response to an item asking if they would use PLATO again if they had a chance, the following responses were observed:

TABLE 3.5

Instructor Response

Response	Number	Percent
Never!	0	0.0
Probably not	1	0.0
Not really sure	6	5.5
Probably would	32	29.4
Absolutely!	70	64.2
	109	100.0%

The major advantages of CBE seen by this group of experienced instructors were that it permitted instruction of a type not otherwise possible (e.g. individualized attention and real-time simulations of chemical or biological experiments) and that it gave the instructor a better idea of student needs. Even the disadvantages of CBE most frequently cited by this group could be considered as favoring CBE. The two disadvantages scored most frequently by the group as "major problems" were insufficient terminals for all students (most sites had only 24 terminals) and insufficient computer memory to permit open access to all available materials for every student.

In addition to sites supported as part of the National Demonstration, many other organizations make use of the University of Illinois PLATO system.

Table 3.6 summarizes these users by type. In all cases except "elementary and secondary schools", terminal usage is being supported by the institution involved. No efforts are made to interest new users in the system since demand for access far exceeds current or planned resources. New users are, however, being served by the Control Data Corporation which is rapidly expanding facilities on commercially operated PLATO systems. Three of these commercial systems are currently in operation in North American with many others planned.

TABLE 3.6

Major Users of Urbana PLATO System as of December 1976

Type of User	Number of Organizations	Number of Terminals
Universities	36	461
Community Colleges	6	119
Elementary and Secondary	5	64
State and Federal Government	11	49
Military	12	90
Commercial	8	12
System Support and Research	1	64
	79	859

Note:

The users shown here are limited to those with dedicated communications lines to Urbana. Additional users with lower rates of usage share dial-in access.

3.4 EDUCATIONAL EFFECTIVENESS- DISCUSSION

CBE is a medium rather than a specific instructional treatment. Thus, a demonstration of superior teaching by CBE is in itself of little value other than as proof that the medium does not hinder instruction. The field of educational innovation has been plagued by projects in which the highly motivated originators of an innovation are able to show dazzling results which, unfortunately, dwindle to nonsignificance when the device or technique is used under more realistic conditions. Both to prevent such an unrealistic "demonstration" and to maximize chances for observing novel approaches to use of the medium, the PLATO curricular development efforts made maximum use of personnel from the institutions. Personnel employed by CERL to provide the day-to-day contact with these institutions for coordination and communications were typical of the population of educators who might be hired to provide such services on a permanent basis by organizations which had the limited financial resources characteristic of educational institutions.

A total of 66 persons were employed during the duration of the National Demonstration in the areas of development and management of curricula. The median salary paid was $10,500 per year and most had either bachelors- or masters-level degrees (usually in some field of education). As might be expected at this salary level, turnover was rather high with a median duration of employment of 12 months (mean 16.25 months). Some personnel did have higher qualifications, a longer period of employment, and/or a higher salary. During initial implementation efforts, for example, personnel with special qualifications in adult education and implementation of educational technology were employed temporarily to smooth the introduction of PLATO into the community colleges. Curricular development teams also tended to have personnel with more experience. However, during the entire project only six persons at the doctoral-level were employed in curriculum development. While a few of these people had experience in various curriculum development projects, none could be described (at the time of their employment) as an "expert in CBE curriculum development". With rare exceptions, they were learning to use a medium that was totally new to them.

Professional support from experienced CERL employes was largely limited to aid in learning use of various features of the PLATO system. Initial support in the area of instructional design and evaluation was supplied only by personnel who had CBE backgrounds roughly equivalent to those of the curriculum design teams. Later support in formative evaluation was given by persons with substantial experience in CBE, but was limited mainly to aid in test design or analysis of data required for special reports as part of the National Demonstration. Thus, materials produced by these groups should be representative of what could realistically be expected of persons who were qualified in their subject-matter fields as teachers but who were not highly experienced in use of CBE or (in many cases) in the management of major curriculum development efforts. The results of this approach are evident in the sections of this report which cover each subject-matter area. In brief, an impressive quantity of material of commendable quality resulted. The approach is probably not the most efficient method of producing effective instructional materials, but it did provide a good deal of data on author behaviors. These data are now being used to complete several studies on general techniques for effective use of CBE under a project funded by Advanced Research Projects Agency.

In several areas, personnel from the curricular design teams made substantial contributions to tools and techniques that were of value to all users of the PLATO system and, ultimately, to users of all flexible CBE systems. One example is the collection of data on student interactions with

CBE materials. PLATO allows one to store detailed information on such interactions for each student. A basic program for storage and analysis of these data was written by members of the CERL evaluation staff. This program was extensively supplemented and expanded by members of the CERL Community College staff and was used to provide summary tables, graphical displays, and statistical analyses of value in lesson and student evaluation. Techniques suggested by the experience gained in analysis of the great variety of data from the various community college efforts are now being developed further under separate funding. For example, promising relationships have been found between performance on standard tests and selected student behaviors within CBE lessons.

Evaluation of effectiveness of instructional materials will be done by the external evaluator (ETS). However, it will be useful to consider one major generalization that may be drawn from formative evaluation data. Projects which tended to use CBE as a treatment rather than as a medium did not produce materials which showed great success. Simply generating instructional materials (even materials that made exemplary use of features not available through any other medium) is not sufficient to insure effective instruction. As with any medium, success goes to the instructional designer who takes special pains to insure a match between needs and abilities of student, needs and abilities of teachers, and design of instructional materials. In some cases, results of such care will be clearcut. In Community College Math, for example, a comparison between a PLATO class and a non-PLATO class on an ETS-administered performance test showed significantly higher mean scores for the PLATO group ($\underline{t}(48) = 3.168$, a difference this large or larger would occur by chance alone only 3 times in 1000). In other cases, the normal "noise" of intact-group comparisons may obfuscate results. Table 3.7 shows results of three tests for a PLATO-non-PLATO comparison (again in Math).

TABLE 3.7

Performance Scores for Math Students

		Prerequisite	Pretest	Posttest
PLATO	18	58.11 (21.80)	12.44 (9.85)	35.39 (9.89)
non-PLATO	22	71.91 (16.57)	11.23 (8.30)	32.59 (10.42)

Notes:

Entries are mean scores (standard deviation). "Prerequisite" scores are for a test of skills that were prerequisites for the course. "Pretest" and "Posttest" scores are for tests of the skills taught in the course. Both sections were taught by the same teacher.

Scores on the "pretest" (which covered only the material to be taught) as well as the "posttest" showed no significant difference between the two groups. However, a test of skills which were assumed to be prerequisites for the course indicated that the PLATO group actually did not begin the course with all the skills needed to understand the instruction to be given. Thus, the PLATO group started at a lower point and ended at a slightly higher point than the non-PLATO group. When this difference in starting levels is statistically compensated for by use of analysis of covariance procedures, the PLATO group is shown to have learned significantly more than the non-PLATO group ($F(31,36) = 12.099$, a difference this large or larger would be expected to occur by chance alone only 14 times in 10,000). The major reason the PLATO materials were able to cope with students who were, strictly speaking, not prepared for the course was that a great deal of care had been given to determining the actual (rather than assumed) levels of student skills. It had been noted that many students were entering these courses without an adequate background. Therefore, materials were designed to permit such students to take special remedial segments where needed on an individual basis. If the materials had not contained automatic remediation, it is likely that many students who did not have the assumed prerequisites would have been forced to drop out of the course. In other instances, the instructor might have been automatically alerted when PLATO detected a student with problems that could be alleviated by individual attention. The point to be noted is that CBE materials can be effective only when they are designed as a part of the total instructional setting. In addition, CBE is likely to be particularly effective when it is used to adapt instruction to the needs of students with widely differing backgrounds.

3.5 A FORMATIVE ASSESSMENT OF THE PLATO ELEMENTARY MATHEMATICS CURRICULUM*

3.5.1 Summary

The PLATO Elementary Mathematics Curriculum consists of three quite independent "Strands" -- Whole Numbers, Fractions, and Graphs, all designed for use in elementary grades 4, 5, and 6. Apparent relative success, as indicated by summarized performance results communicated to us informally by Educational Testing Service, is in the order: Fractions (most successful), Graphs, and Whole Numbers.

The Fractions Strand was quite different in several respects from the other two. For example, most Fractions lessons adjusted the difficulty of tasks presented to the student on the basis of the student's own recent performance, while few or no lessons of the other Strands did so. Also, most Fractions lessons used a mastery-of-skill criterion to determine when to advance the student to new lessons, whereas few Whole Numbers and Graphs lessons had this feature. In addition, the Fractions Strand included by far the most extensive provisions for integration of PLATO mathematics instruction with the regular mathematics instruction of the classroom teacher.

Since it is altogether plausible that differential presence of such characteristics should be related to differential success, we entertain the formative judgment that future PLATO work in basic skills areas should strive to follow the example of the Fractions Strand in these respects.

3.5.2 The Three Strands

The topics covered by the Whole Numbers Strand, including meanings, "facts", expressions, algorithms, and word problems for each of the four operations, are

*This section covers only student performance test results. Other goals and outcomes are discussed in Section 4 ("Elementary School Mathematics").

mostly standard ones for grades 4-6.

The topics covered by the Fractions Strand are also mainly standard ones for grades 4-6: meaning of fractions, mixed numbers, and decimal fractions; ordering; equivalence and conversions; common denominators; and addition, subtraction, and multiplication of fractions and mixed numbers.

The Graphs Strand is concerned mainly with topics that are not usually taught in grades 4-6, such as Cartesian coordinates, signed numbers, variables, and functions.

Each of the three Strands was developed by its own author group, which had its own philosophy of education and its own approach to the use of the PLATO medium, and there was little formal coordination among the three groups. Hence, as one might expect, the Strands vary in structure, approach, style, and conventions, as well as in content. Thus, in many respects they have the character of three separate attempts to use PLATO in the elementary mathematics classroom, even though they were jointly implemented and managed during the two successive curriculum trials whose results are discussed here.

3.5.3 Performance Results

During 1974-75, PLATO math lessons were used in about a dozen demographically variegated elementary (4th, 5th, and 6th grade) classrooms in Champaign-Urbana; the same was true in 1975-76. In each year, Educational Testing Service conducted an external evaluation study using the available PLATO classes together with about a dozen non-PLATO classes intended to be matched by grade, ability, and neighborhood to the PLATO classes. A major component of each study was measurement of performance gains in each of the three content areas by means of pre and post testing. The instruments used, one for each content area, were developed by ETS in consultation with senior authors from the respective PLATO Strands. Except for a modest revision of the Fractions test in summer 1975 (which consisted mainly of increasing the number of items on equivalence, and including a page on decimals), the original three tests were used unchanged for both administrations in both years.

ETS has never officially communicated to us any findings for either year. However, we were informally given tables of item data from the 1974-75 trial; and we have informally been told ETS's assessment of the Strand-by-grade outcomes for 1975-76. Table 3.8 summarizes Strand-by-grade results for the two years.

Strands	Fractions			Graphs			Whole Numbers		
Grade	4	5	6	4	5	6	4	5	6
1974-75	+	+	0	0+	+	0	-	0	0+
1975-76	+	+	+	0	+	+	+	0	0

Table 3.8 Relative performance results, PLATO vs. non-PLATO, in two successive curriculum trials. A plus sign (+) means that PLATO showed significantly ($\alpha = .05$) superior gains; a minus sign (-) means that non-PLATO did so; (0) means there was no significant difference; and (0^+) means the superiority of the PLATO gains approached ($p<.07$), but did not achieve, the designated level of significance. 1974-75 results were derived by CERL from tables of item difficulty data, via binomial tests of item difference scores. (The binomial test's assumption of experimental independence of observations was judged to be met, inasmuch as the tests were untimed, and the opportunities for inter-item cueing (except possibly in the case of the Graphs test) were judged to be small.) Results for 1975-76 were communicated to us verbally by Spencer Swinton of ETS in December 1976.

Given that the two rows in Table 3.8 were obtained by different people, using different methods, from data of two trials run under very different conditions (see section 3.5.6d), the degree of apparent order there displayed is surprising; in each year, the Fractions results appear strongest, the Graphs results next, and the Whole Numbers results last. And, for every Strand, the 1975-76 results were better than the 1974-75 results (possibly due, in some part, to the better PLATO running conditions that obtained in 1975-76 (see section 3.5.6d)).

3.5.3.1 ETS Covariance Analyses for 1974-75

The outcomes for 1974-75 given in Table 3.8, which were computed at CERL from the item data tables received from ETS, are confirmed in their main outline by the results of analyses of covariance performed by ETS, based on (presumably) the same body of test data from which were computed the tables of item data that we were given. The relevant results of these analyses of covariance are summarized in Table 3.9.

	Probability	Adjusted Means (all pupils)	
		PLATO	non-PLATO
Fractions	.000	5.6	2.8
Graphs	.218	3.9	2.8
Whole Numbers	.952	9.8	10.1

Table 3.9 Results of three analyses of covariance. Each "Adjusted Means" entry is a measure of posttest performance adjusted for pretest performance. Each "Probability" entry gives the likelihood that the observed difference of adjusted means (PLATO vs. non-PLATO) could have occurred by chance alone. (These analyses were done by ETS.)

The table says that the likelihood that the favorable-appearing Fractions test results could have occurred by chance is vanishingly small, while the likelihood that the favorable-appearing Graphs test results could have occurred by chance is quite high (better than one chance in five). The observed difference in Whole Numbers adjusted means is insignificant, since larger differences could have occurred by chance alone.

The covariance results cited were conveyed to us informally by ETS. Further details of the analyses should be obtained from ETS.

3.5.3.2 CERL Matched-Pair Analysis

Just as the ETS covariance analyses for 1974-75 are consistent with the CERL results shown for 1974-75 in Table 3.8, the ETS results shown in the same table for 1975-76 are confirmed in part by a CERL analysis.

For 1975-76, ETS permitted us to obtain the full student-by-item matrix for two of the ETS tests--the "comprehensive" standardized test, and the ETS achievement test on Fractions. We used the former as a matching instrument, in order to look at the results for the latter with initial ability/achievement differences removed, insofar as possible. This was done mostly to obtain specific information for lesson improvement, but the results are presented here in the form of an overall comparison.

Matching was carried out as follows--

> The pairings of PLATO and non-PLATO classes which ETS had set up at the beginning of the trial were used as a beginning point. Within each such pairing of classes, PLATO students were paired with non-PLATO students on the basis of the three subscores, and the total score, of the standardized test. Stringent matching criteria were employed, but the number of matched pairs obtained was 75% of the maximum number of such pairs that could possibly have been obtained. The adequacy of the matching operation was checked by examining the means and standard deviations for the two parts of the sample on each of the subscores, and on the total score, of the standardized test. For all four scores, the means were never different by more than a few tenths of a point (.01--.1 S.D.), either on raw scores or on corresponding grade equivalent scores, and the standard deviations were also very nearly equal.

Figure 3.1 shows the matched-pair results for the ETS Fractions test. Each vector in Figure 3.1 is associated with an item from that test. The tail of each vector (shown as a circled item number) is plotted at the point determined by the percentages of PLATO and non-PLATO students who passed the associated test item on the pretest. The head of the vector (labeled with an uncircled item number) is plotted at the point determined by corresponding percentages from the posttest. Since PLATO is on the ordinate, a steeply sloping vector indicates better relative performance by the PLATO group. A slope less than 45 degrees indicates better relative performance by the non-PLATO group. As the figure shows, only a handful of vectors have slopes less than 45 degrees. The overwhelming majority have slopes greater than that, and many of them are quite steep.

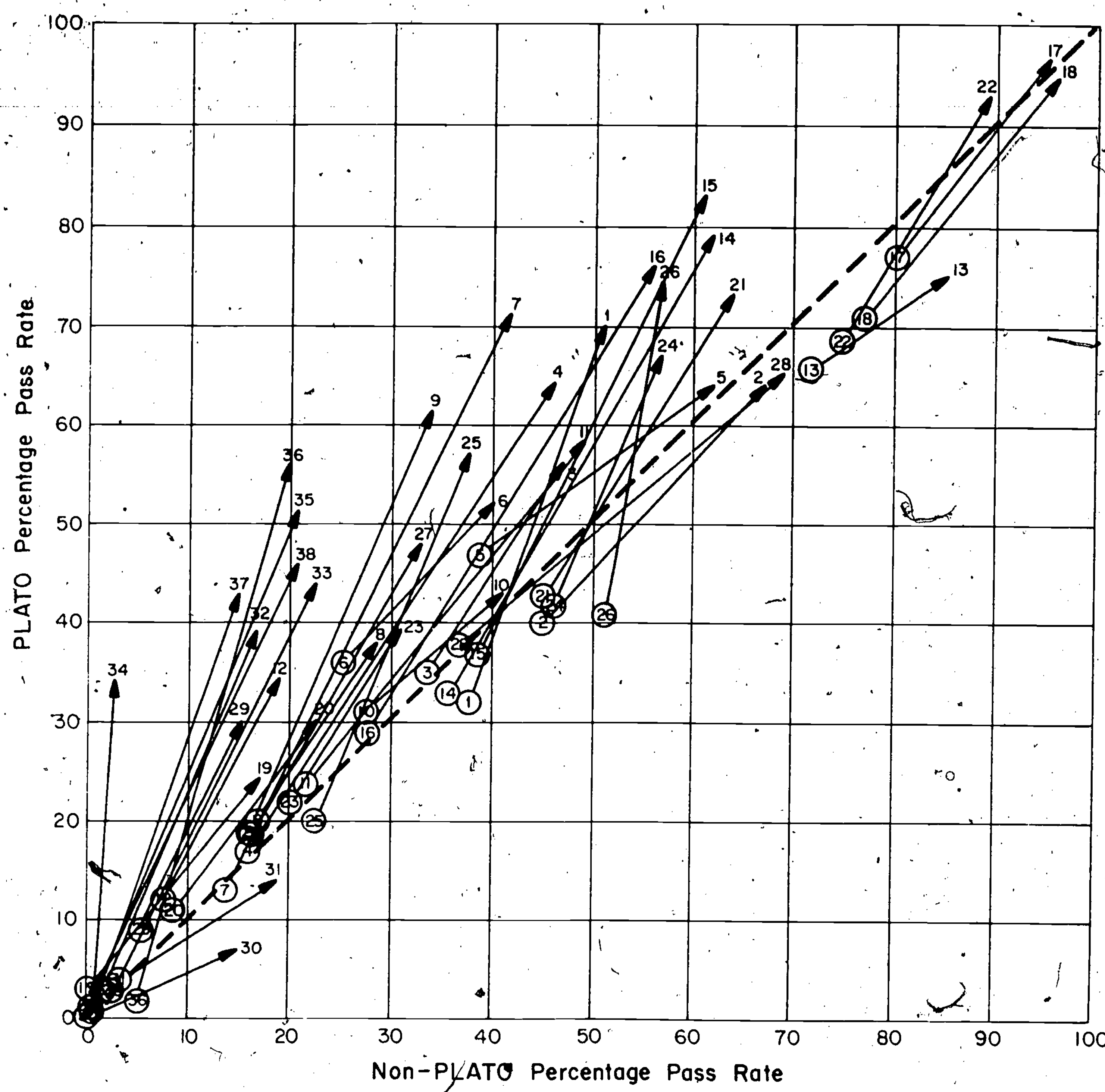


Figure 3.1 Matched pair results for Fractions (1975-76). Each vector represents an item on the ETS Fractions test. The figure is based on the 122 matched pairs for whom complete results from that test were obtained. (Sixth-grade classes Ha, Ya, and Jo are excluded, because the old, incomplete, form of the Fractions test was accidentally administered to classes Ha and Ya at pretest time, and because classes Ha and Jo appear to have spent an unusual amount of class time on Fractions.)

The probability of so many of the slopes exceeding 45° by chance is p<.00001 (n=36, s=31). The binomial test is justified given that the Fractions test was untimed and given that the opportunities for inter-item cueing were judged to be small. When the 19 items on equivalence and decimals, where inter-item cueing is conceivable (though unlikely), are neglected, the result is p<.025 (n=17, s=13). The binomial test is, of course, extremely conservative, in that it ignores the information contained in the magnitudes of the slopes and in the lengths of the vectors.

These results would appear marked enough to have practical, as well as merely statistical, significance; and they confirm the strong showing found for Fractions in 1975-76 by ETS. We only regret we do not have the data to do similar analyses for Whole Numbers and Graphs.

3.5.3.3 CERL Attempt at Analysis of the Standardized Test

Because the increment of effort required was small, relatively speaking, an attempt was made to analyze the standardized test itself in the same way just shown for the 1975-76 Fractions data, but the results were disappointing. Most of the vectors had slopes favoring PLATO, but the difference from 45 degrees was small for almost all items. This is consistent with previous experience that multiple-choice items are generally too unstable to repay this kind of analysis.

3.5.4 Time Data

The amounts of time that PLATO students spent working in the various Strands are important data in connection with attempting to interpret performance results. Figures computed from on-line records of student time in Strand-lessons are given in the Table 3.10 for 1975-76.

	Whole Numbers	Fractions	Graphs
Per cent	50.4%	35.6%	14.0%
Mean Hours	22.9	16.1	6.3

Table 3.10 Measures of student time-on-PLATO spent in lessons of the various Strands. (If times for two disputed lessons on whole numbers are neglected, the respective percentages are 48.1%, 37.3% and 14.7%, and the Hours figure for Whole Numbers is 20.8.) Times are given as they stood on April 30, since most ETS posttests were administered just before or just after April 30.

The figures show that students spent about as much time on Whole Numbers as on the other two Strands combined, and that they spent relatively little time on Graphs. In gross terms, the same was true for 1974-1975, but precise figures for that year are not available.

Amounts of time spent by teachers, both PLATO and non-PLATO, in class work in the three content areas is also important to interpreting the performance results. Unfortunately, data from the retrospective "Math Coverage Questionnaire" which ETS administered to PLATO and non-PLATO teachers at the end of the 1975-76 trial present very serious difficulties of interpretation. (The questionnaire is discussed further in Section 3.5.7.)

Only in the case of Graphs, because responses relevant to Graphs do not vary much across grade and treatment, does it seem safe to interpret the questionnaire data. These data seem to show that Graphs topics were little treated in the non-PLATO classes, or even in the PLATO classes beyond the students' exposure to the PLATO lessons themselves. On the average, teachers designated Graphs topics as receiving "extensive coverage [in class]" in only 2.5% of the possible instances, whereas they designated Graphs topics as receiving "no coverage [in class]" in 72.5% of the possible instances. Thus, the finding in several cases that the PLATO classes outperformed the non-PLATO classes on the ETS Graphs test can be taken as evidence that the

PLATO Graphs lessons teach the topics in that test to a measurable degree, but not as evidence that they achieve better results than "conventional methods".

3.5.5 Discussion

In Section 3.5.6, some general discussion is given to external factors which might have contributed to the observed performance results. However, data necessary to evaluate the importance of these various factors is not available to us. We could speculate further in such directions, but it would seem more useful, instead, to examine the three Strands themselves, in the hope of finding differential characteristics which might account for some of the observed differences in performance results. Results of such an examination could provide useful guidance to future PLATO curriculum efforts.

In fact, it has been known for some time that the most successful Strand, Fractions, was different in several important respects from the other two Strands. Among them--

a. Only the Fractions Strand fully exploited the ability of PLATO to adjust instruction to the performance of the student. Most of the Fractions lessons adjusted difficulty constantly for the individual student on the basis of his recent performance, often through 10 or more levels, and (in 1975-76) provided constant feedback to the student about his progress through the levels; in addition, Fractions lessons used mastery-of-skill criteria to determine when to advance the student to new lessons. Only the Fractions Strand was individualized in this thoroughgoing sense, as is shown by the data in Table 3.11.

	Fractions	Graphs	Whole Numbers
All lessons (except quizes)	84	61	73
Required lessons	79	57	55
Adjustive (strict def.)	57	0	0
Mastery (strict def.)	54	1	1
Adjustive (weak def.)	58	8	5
Mastery (weak def.)	57	2	7

Table 3.11 Characteristics of lessons of the three Strands. Each entry is the number of lessons having the designated characteristic.

Lessons were classified according to both a strict and a somewhat relaxed definition of adjustiveness; likewise, they were classified according to both a strict and a somewhat relaxed definition of mastery-of-skill criterion. The weaker definition in each case allowed all reasonable borderline cases to be included.

There is no implication, of course, that EVERY lesson should adjust difficulty and demand mastery-of-skill. These concepts are appropriate only to lessons whose purpose is, in fact, to produce mastery of skill, and all three Strands had objectives beyond mastery of their respective target skills.

b. All three Strands were designed to be used by the classroom teacher (not to be independent of the teacher), but only the Fractions Strand gave sustained attention to the problems of integrating PLATO instruction with regular classroom instruction. Specifically, the Fractions support machinery included effective on-line and off-line student data feedback to teachers, a handbook to help teachers understand and use the feedback, a 100-page illustrated teacher's guide to help teachers understand and use the Fractions lessons, and extensive off-line student materials. In 1975-76, data feedback was provided for all three Strands in the form pioneered by the Fractions Strand in 1974-75.

The following tables give some further information about the other factors.

	Fractions	Graphs	Whole Numbers
Teacher's manual provided?	Yes	Yes	No
Looseleaf for teachers?	Yes	No	-
Revisions before 1975-76:	Two	None	-
Edition used in 1975-76:	Nov 75	Jun 74	-
Number of pages:	108	80	-
Pages over 1/3 full:	99	45	-
Number of illustrations:	223	5	-
# of screen illustrations:	218	0	-

Table 3.12 Characteristics of teacher's manuals provided by the various Strands.

	Fractions	Graphs	Whole Numbers
Off-line materials provided?	Yes	Yes	No
Keyed copy for teachers?	Yes	?	-
Integrated with manual?	Yes	No	-
Integrated with feedback?	Yes	No	-
Number of pages:	65	24	-
Number of tasks:	445	139	-

Table 3.13 Characteristics of off-line student materials provided by the various Strands.

3.5.6 Words of Caution

The performance results discussed in Section 3.5.3 are those of two small-scale educational studies conducted under naturalistic conditions. That being so, it is necessary to give some consideration to the various alternative explanations which could account, in whole or in part, for the results reported. There are a number of them; only a few of the more important ones will be discussed.

a. Aside from the fact that, in each case, one set of classes used the PLATO Elementary Mathematics lessons and the other set did not, we know relatively little about what actually went on in the classes included in the studies. (Sections 3.5.4 (above) and 3.5.7 (following) also relate to this problem.) Thus, there is no way to rule out the possibility that parameters other than the use of the PLATO curriculum materials were important in determining the observed results. Different amounts of teacher time spent on different topics in different classes, for example, could have had a large effect on the results we have.

b. Neither teachers nor students were randomly selected, and the total number of teachers involved was quite small. Thus, the results observed could easily have been due, at least in part, to accidents of sampling. One known bias: PLATO teachers were largely self-selected. However, the differential success of the three Strands suggests that such factors, though almost certainly present to various unknown degrees, were not overriding.

c. As is customary in educational experiments, the trial was not "blind", let alone "double-blind". Thus, it is altogether possible that the observed results were influenced by irrelevant incentive effects (Hawthorne effect, John Henry effect, Pygmalion effect, etc.). One possible source of such effects, in addition to the generally high visibility of PLATO: PLATO teachers received extra pay. (On the other hand, the differential success of the three Strands suggests, once again, that such effects, if present, were not overriding.)

d. The circumstances of the PLATO trials were in a number of respects far from optimal. The fact that the three Strands were the products of three quite separate groups led to some jury-rigged compromises in the way the curriculum was managed. Particularly unfortunate in 1975-76 was the widespread use of "mixed" or "balanced" schedules--ones where a student would receive main-line instruction in two, or even all three, different Strands each week. (By actual count, about 79% of all student-weeks had "mixed" schedules.) This practice entailed constant re-orientation on the part of the students, and limited the opportunity of PLATO teachers to coordinate their classroom work with the PLATO curriculum.

In 1974-75, severe system limitations (system instability, inadequate computer memory, and lack of touch panels) prevented "mixed" schedules, but caused serious problems of other kinds. Briefly, Whole Numbers and Graphs ran for a long time, but under poor conditions; whereas Fractions ran under good conditions, but only for a short time (students, on the average, completed less than half the available Fractions sequence).

In the final analysis, there is no way to rule out the possibility that all three Strands of the PLATO curriculum might have shown better results in one or both of the two years if these various difficulties of implementation had been avoided.

e. Except for the standardized test and Fractions test data for 1975-76, most of the data on which the discussion here is based were collected and processed by Education Testing Service (the demands of the ETS Evaluation on teachers and students severely limited the amount of data we could collect independently), and our knowledge of how it was done is minimal. Only summary numbers were made available to us for 1974-75; we have not had access to original student tests and questionnaires, nor to student-by-item matrices derived from them; nor have we any information about the standards/procedures which were used to convert student responses on the open-ended ETS Strand tests into item scores. For the 1975-76 results, we have obtained student-by-item matrices for the standardized test and the ETS Fractions test, but we have only a generalized verbal report on results for the other two Strands. Obviously, it is highly unsatisfactory to have so much of the data from these two trials available only in such pre-digested forms.

More could be said, but the five points given should be sufficient to persuade the reader that, while it seems possible to form useful judgments on the basis of the available results of the two trials, such judgments must be regarded as hypotheses, not as conclusions.

3.5.7 ETS's Topic Coverage Questionnaire

The PLATO and non-PLATO "treatments" were not well-defined in either year's trial, and such data as we have indicate that both "treatments" were markedly and irregularly non-homogeneous (i.e., different teachers did widely varying things). For 1974-75, ETS has not reported any data about what the two "treatments" were in fact like (i.e., about what the various teachers actually did in their math classes during the year). However, at the end of the 1975-76 year, ETS did ask teachers to fill out a "Math Coverage Questionnaire" in an attempt to gather some information of this kind.

To comment adequately on this questionnaire would require many pages. But data concerning teacher contributions is so important to interpretation of the test data that some general comments, at least, are required.

a. The questionnaire was seven pages long and required nearly 100 responses, including 61 six-way classifications. It has the appearance of a rough-draft, and there was no preliminary field testing of it that we know of.

b. The questionnaire came at the end of the year, but attempted to ascertain details of class mathematics activities conducted since the beginning of the year--a procedure which, by itself, renders the data collected rather questionable.

c. There is ample evidence that respondents often did not understand directions, ignored them, or read variant meaning into them, and that many respondents were answering hastily.

d. The questionnaire took no notice of the fact that ETS's posttests were given about a month, more or less, before the end of school. This is important because topics which teachers covered after about April 30 were, as far as the posttests were concerned, not covered at all. However, it is not possible to tell from the questionnaire data which topics were covered before April 30 and which after.

e. In six cases, a single questionnaire covered classes which included children from two, or even three, different grade levels. In another case, just one questionnaire was obtained from a teacher who taught both a PLATO class and two non-PLATO classes. For one group of PLATO 4th graders, no questionnaire data at all were obtained.

For these and other reasons, the questionnarie data present very serious difficulties of interpretation. The operations necessary to convert the raw responses into useful indices necessarily introduce assumptions and judgments, not previously specified, which muddy the interpretation picture still further. Altogether, we do not believe it is possible to extract from these data much that is helpful in interpreting the achievement test data. This is a finding we deeply regret. We hope that with the help of data from classroom observations, teacher logs, interviews, etc. (none of which are available to us), ETS will be able to do better than we at assessing the contribution of the many factors other than PLATO which undoubtedly influnenced the observed performance results.

3.5.8 Conclusion to Section 3.5

PLATO is not itself a treatment, and in particular it is not a magic treatment which will always produce good results. Instead, PLATO is a medium which can be used well or badly. Experience with the Elementary Mathematics Curriculum suggests that among the factors which can contribute to effective use of PLATO are: a) having lessons adjust difficulty in response to the recent performance of the student, b) using mastery-of-skill criteria to determine when to advance students from lesson to lesson, and c) making generous provision for integrating PLATO lessons with the ongoing work of the classroom. A curriculum, especially a basic skills curriculum, which does not make appropriate use of these techniques may not be using PLATO as effectively as it could and should.

Of course, these techniques are themselves tools which can be used well or badly. A large element of judgment, which as yet does not lend itself easily to description in quantitative terms, plays a crucial role in determining the success or failure of instructional design and implementation efforts. So attention to adjustiveness, mastery criteria, and integration with teachers' activities does not guarantee success. But, in skilled hands, these techniques seem able to make important contributions to success. We hope that continuing PLATO efforts in basic skills areas will enable us to explore the possibilities further.

3.6 EVALUATION PROBLEMS

Three major evaluation problems encountered during the National Demonstration seem sufficiently general that they warrant description and discussion.

First is the matter of clear specification of evaluation goals. In retrospect it appears that ETS and CERL each had differing views of what were proper goals of the external evaluation. Early ETS personnel concentrated, for example, on the products of the curriculum design projects at a time when CERL personnel were convinced that evaluation of the processes being carried out was most important. From the view of the ETS personnel, PLATO had been presented as a completed instructional product ready to be evaluated for the market. From the view of CERL personnel, PLATO was a vehicle which would permit study of a variety of techniques of implementing a new instructional medium. Each of these views could be defended and little would be gained by claiming either as "the" correct view. The important outcome was that each of these organizations in following what they perceived as the expected direction of the Demonstration wasted resources that could have been better used. ETS, under the assumption that initial specifications of courseware objectives were firm, began development of tests which turned out to be inappropriate for the materials ultimately produced as outcomes of an evolutionary design process. CERL, under the assumption that the process of learning to use a new medium was of major interest, spread limited resources over so many different projects that chances for clearcut success of any one were restricted. Since the differences in viewpoints became apparent only after many months of interaction, it seems clear that future participants in projects for which clear precedents are not available should be very cautious in assuming that general descriptions of planned activities of others can be interpreted in only one way.

Second, is the matter of conflicting evaluation efforts. Materials developed during the National Demonstration had to undergo a formative evaluation during production to provide designers with information needed for modification and improvement. They also underwent a summative evaluation to determine their effectiveness as a finished product. Since both of these evaluations require collection of substantial quantities of opinion and performance, it was seen that sharing of data between evaluators would minimize duplication of effort and undue demands on the limited time of student and instructors. Since it was felt that the needs of the external evaluator to insure the validity of collected data was stronger than the need of the internal evaluator to insure prompt feedback to designers, ETS personnel agreed to perform all collection of data from off-line tests and to share these data within a few days with design groups. Unfortunately, changes in personnel and fears of possible misuse of these data (to "teach to the test item") resulted in delays of up to a year between data collection and sharing. As a result, many materials never benefited from a final revision cycle based on data from students from more than one institution. A solution for this problem is not simple. Clearly, something is awry when the act of evaluation leads to a possibly inferior product. Yet, if an external evaluation is necessary, one would hesitate to compromise its independence. Probably the only workable compromise is for both types of evaluations to be carried out internally and for the summative evaluation to be subjected to an independent audit or meta-evaluation.

The third problem is the matter of special skills being needed for evaluations of novel technologies. There are certain basic skills in the areas of experimental design, observation, test development, and data analysis that any competent evaluator is expected to possess. In addition, special skills and knowledge must be possessed or acquired in order to design and perform an effective evaluation in a specific area such as early childhood education or CBE. ETS recognized this need in subcontracting certain portions of the evaluation to nationally recognized specialists. In addition, their own personnel acquired skill and use of the PLATO system. The uniqueness of the PLATO system, in fact, made it necessary even for the subcontracted specialists to devote time to understanding details of this CBE system before they were able to make useful contributions. In retrospect, this time required for acquisition of skills that are unlikely to benefit the external evaluators in other situations seems to be a waste of their valuable time. A staff of qualified evaluators with these special skills already existed at CERL. At no time during the National Demonstration was this internal staff supported for more than two full-time-equivalents of time for that effort. Even this level was present only at the end of the Demonstration and then largely in support of data analysis (although limited earlier support in formative evaluation had been given also). With limited additional support, generalizable studies of CBE systems functioning and instructional design could have been produced by the group (several such studies are, in fact, now in progress under support of the Advanced Research Projects Agency). Freed from having to learn the esoteric nuances of one specific CBE system, the talents of ETS personnel could have been used to perform a thorough audit of the resulting internal evaluation and technical reports. Such a role was indeed assumed by ETS in the case of most of the technical information on system usage and reliability. These last data were collected almost entirely by the CERL evaluation staff as a part of their normal duties and would have been available even in the absence of an external evaluation.

3.7 PERSONNEL

The following persons were members of the PLATO Educational Evaluation and Research Group (PEER Group) during the National Assessment. Their contributions to this project are briefly indicated beside their names.

Allen Avner - Chief of PEER group. System reliability and usage. Early versions of student data routines. General aid to Community College groups in collection and analysis of usage data.

John B. Gilpin - Internal evaluation work with the Elementary Mathematics Project. Instructional design and test design support for Community College Mathematics and Elementary Mathematics. Internal Evaluation of Community College English.

Martin A. Siegel - Data Analysis Service Programs. Curriculum Consultant to the Community College Mathematics Group.

Esther R. Steinberg - General Aid in lesson design for Community College groups. Internal evaluation of Community College Mathematics and Elementary Reading.

Kikumi Tatsuoka - Data Analysis and Statistical Service Programs. Design and Data Analysis of some PLATO-non-PLATO comparison study in Community College Mathematics.

Tamar Weaver - Design of student data handling procedures for all Community College projects (except English). Consulting with Community College personnel on gathering of formative data for lesson design and revision.

4. ELEMENTARY SCHOOL MATHEMATICS

The goal of the elementary school mathematics program has been the demonstration of the feasibility and value of PLATO in the mathematics curriculum in grades four through six. In the years from 1973 to 1976 the program has developed over 100 hours of instructional material (averaged for many students), and has delivered approximately 30,000 student contact hours of instruction to about 500 students. Test results and personal response from teachers and students indicate that PLATO can provide an effective medium for learning and teaching.

4.1 STATEMENT OF THE PROBLEM

The intermediate-grade math demonstration came to focus on two sub-problems:

1. The determination of the mathematics-teaching roles PLATO can play in an elementary school classroom.

2. The creation of enough courseware to explore the utilization of PLATO in some of these roles.

These problems necessarily had to be dealt with simultaneously, since without some determination of appropriate roles one cannot design suitable courseware, yet at the same time, without a reasonable body of courseware one can get no empirical results on how well PLATO can play each particular role.

The ecology of an elementary school classroom is complex. In helping elementary school students learn mathematics, teachers ordinarily carry out many different activities: they administer tests, both for diagnostic and for motivational reasons; they correct these tests, sometimes with subtle attention to the precise form and probable cause of the various student errors; they attempt to diagnose student needs; they introduce new ideas, they assign homework, they answer student questions, and much, much more. On their side, students also do many different things: they receive assignments from the teacher; they listen to other students, and get ideas from them; they compete with other students; they consider student remarks and make judgements on them; they do work that they are proud of and show it to other students, or to adults; they are influenced by various peer-group pressures, and they contribute to the creation of peer-group pressures that influence other students; they give answers which embarrass them before other children; they make errors and try to go over their work to find what went wrong; they discover patterns; they explain things to other students; they make suggestions to other students; and, again, much, much more.

Where, among these tasks, could PLATO Play a useful role? In trying to answer this question, several factors must be considered.

Some observers, for example, have feared that the use of CAI in schools would have a harmful effect on children's social development; these observers visualized one child, working alone at a terminal, cut off from social contacts with other human beings, so that their social development was retarded, and (perhaps worse) they did not learn to talk about the work they were doing, so that they failed to develop a "meta" language for discussing mathematics.

Another factor is that since different schools use, roughly, two different approaches to the learning of mathematics, one by rote imitation and drill, and the other by creative analysis of problem situations, some observers have feared that the introduction of computers into classrooms would increase the emphasis on rote arithmetic, and diminish the role of creative heuristic analysis.

More objectively, it seemed that neither of these dangers were inevitable, and one goal for the design of PLATO courseware was to demonstrate that CAI can place quite adequate emphasis on the creative and exploratory aspects of mathematics, and on various forms of social cooperation and interaction.

A third factor concerns the difference between "special" and "operational" testing. Up to a point, at least, a CAI lesson can be tested by itself, as a special activity by students. We have called this "special testing." Some information can be gained from special testing -- for example, confusing wording on ambiguous diagrams can often be identified -- and a great deal of special testing has been done on every PLATO lesson, but special testing can not be used for effective evaluation of how PLATO (or any particular lessons) will function in typical classroom implementation. Special testing is in fact, too special, too unusual. Testing lessons when they are embedded at their intended point in a curriculum that is in routine, day-to-day use in classrooms, we have called "operational testing." Only from operational testing can one infer how PLATO (or the lessons in question) will function in regular classroom implementation.

This implies that the demonstration had to have enough courseware for regular day-in, day-out usage. In fact, enough courseware has been created to provide a curriculum that occupies the average intermediate grade student one half hour per day, every school day, for more than one school year (that is, the average student will not complete the course in one year). When lessons are tested, embedded into this regular usage, one gets a more reliable indication of their value in routine implementation.

Finally, if PLATO is to be a helpful tool for teachers, and not an added nuisance, teachers must be able to assign students to appropriate study units with very little effort; and teachers must get highly readable feedback on student performance in order to monitor what students are doing (and in order to know what assignments to make). Furthermore, if, for any reason, a teacher does NOT make an assignment for some student, PLATO must include a default student-scheduling procedure that will schedule the student in the best way possible based on the accumulated performance record (stored in computer memory) of that individual student.

4.2 SUMMARY OF THE PROGRAM

The elementary mathematics demonstration was set up with enough courseware to allow students to work on PLATO one half hour each day, every school day, for one year. The courseware was developed in three strands, as follows:

1. Whole number arithmetic, including:

   meanings of operations

   computation techniques and practice

   algorithms

   place value

   renaming and symbols

   word problems

2. Fractions, mixed numbers, and decimals, including:

   meanings of fractions and mixed numbers

   equivalent fractions

   addition, subtraction, and multiplication of fractions and mixed numbers the meaning of decimal numerals

heuristic approaches to problem solving

3. Graphs, variables, functions, and equations, including:

signed numbers (integers and rationals, positive, negative, and zero)

variables and open sentences

exponents

graphs

the representation of functions by graphs, tables, and formulas

This courseware was designed for a wide range of student abilities and backgrounds, intended for grades four through six. In most schools there are also many students in grades seven through nine who have not mastered this material, and review and remediation at these grade levels might be an especially important use of such courseware in the future.

It should be stressed that the present courseware has undergone extensive "special" testing, as defined above, but has had only one year of "operational" testing, and has never gone through appropriate micro-assessment in an operational setting; it has therefore never been revised on the basis of such feedback data. It represents a respectable "first draft," largely free of flagrant flaws, but NOT improved by any extensive use of feedback data. In particular, there has been no chance to make empirical comparisons of alternative versions. We do not consider it a finished product.

An individual child's half-hour session for the day is presented to him -- having been "computed" by PLATO from his individual past record of performance, taking account of whatever inputs the teacher has made, and using a default scheduling procedure whenever teacher planning inputs have not been made.

The typical half-hour session is divided into three parts (or slots), and is designed and "computed" roughly as follows. The second of the three parts is viewed as the main new lesson, and is computed first, from "curriculum trees" and invididual records of previous student performance. Once the "second slot" has been planned, PLATO in effect asks, and answers, the question: "if this is to be our main work today, what review of what topics should precede it?" The answer is assigned for the first slot, or else the first slot is filled with other review material, or even with preliminary material intended to build readiness for other new lessons that will be coming up soon. Finally, the third slot is filled with material intended to be particularly enjoyable (but, simultaneously, educationally valuable, either as review or as drill), often cast in some sort of "game" format. Wherever feasible, students are given their choice of activities, or of alternative forms of activities, or of non-curriculum matters within lessons (e.g., within a game, students can choose the name which PLATO calls them, and choices such as "Superman" or "The Greatest" are common). In fact, teacher inputs and student choices combine to allow quite flexible uses of the three slots. (For the 1976-77 year, it will be possible for teachers to arrange for each session to consist of N slots, where $1 \leq N \leq 7$.)

For many lessons there are two versions: a "regular" version, intended for students who are encountering it for the first time, and a "fast" or "review" version for students to use as a quick review; while both versions are paced by student performance (so that the "regular" version can move quickly if students do well, and the "review" version can move slowly for a student who needs extra help), the "review" version is ordinarily shorter and faster.

4.3 THE DIFFERENT ROLES THAT PLATO CAN PLAY IN A CLASSROOM: EXAMPLES OF COURSEWARE

The versatility of the PLATO system and its graphics capabilities allow it to play many different roles in a classroom. This section describes a few of the roles that we have explored in the elementary school mathematics curriculum.

PLATO can introduce a new mathematical idea. This is done via the "paradigm" teaching strategy[1]. The student is asked to perform some action which he is easily able to do, after which his act is re-interpreted. For example, to introduce the fraction 1/3, the student is asked to share a candy bar equally among three children; when he has done this, he is told that he has given each child 1/3 of the candy bar.

The PLATO screen can present pictures that have precisely the property that is relevant to the immediate task. These pictures can help introduce new tasks, and can later be summoned as aids when students seem to need them.

PLATO can provide additional motivation for drill or practice activities.

The two preceding roles can be illustrated by the lesson "Speedway," from the whole number arithmetic strand. Figure 4.1 shows five plasma panel displays from "Speedway." Exactly what displays a student sees as he works through a lesson will depend upon his individual performance, but these five displays are suggestive of the possibilities. The first panel occurs at the beginning of the lesson, and is a typical "choice page," allowing the student a maximum number of choices within the overall planned

[1] Explanations of this are in: Davis, Robert B., "Naive Foundations for a Theory of Mathematics Learning," Learning and the Nature of Mathematics, ed. William E. Lamon, Science Research Associates, Inc., 1972 and Davis, Robert B., "Two Mysteries Explained: The Paradigm Teaching Strategy, and 'Programmability'," Journal of Children's Mathematical Behavior, Supplement No. 1 (Summer 1976).

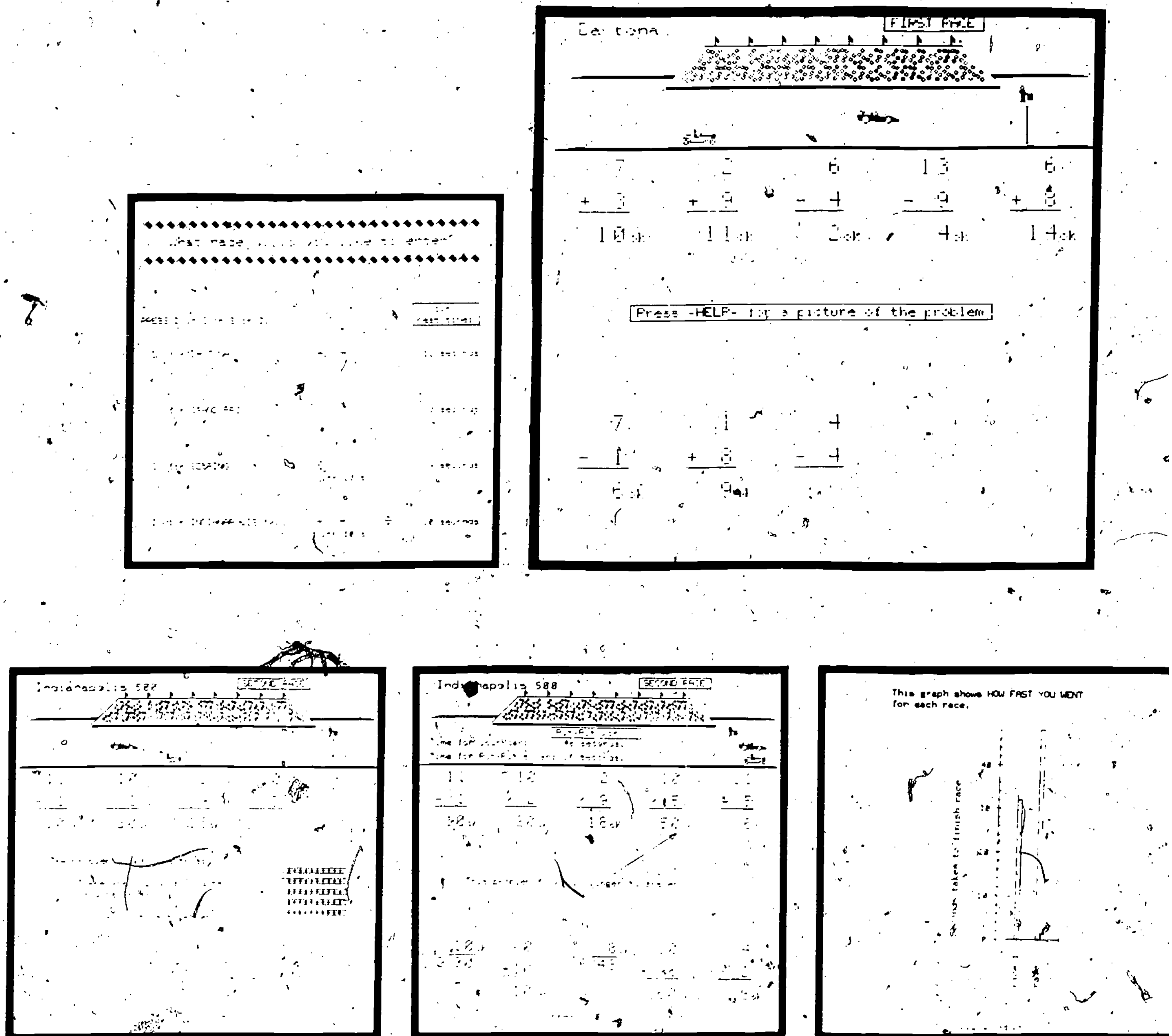


Figure 4.1. Five Typical Panels from the Lesson "Speedway"

curriculum structure. The second panel shows the "race" in progress -- as the student answers questions, PLATO uses his speed and accuracy in answering to determine the speed with which the student's car advances along the track. (The opposing race car has its speed determined by the student's past performance, or, if the student prefers, by a rate which he sets arbitrarily.) Panel III shows the kind of "help" picture that PLATO displays when student performance suggests the need, or when the student himself requests it by pressing the "HELP" key. Panel IV shows one type of feedback that is reported back to the student, and Panel V shows another form, which serves the dual purpose of giving the student detailed data on various aspects of how well he is doing, while also providing experience in the use of graphs, one of the mathematical topics that the student is studying.

The use of "meaningful pictures," or "low-inference structural pictures" -- where the relevant mathematics can be "seen" in the picture itself -- can also be illustrated by the lesson "Subtraction with Sticks." In terms of manipulatable physical objects, place value base-ten numerals can be represented by tongue depressors (for "units" or "ones"), bundles of ten tongue depressors held together by a rubber band (for "tens"), a plastic sandwich bag holding ten such bundles (for "hundreds"), and so on. "Borrowing" or "regrouping" for subtraction is then accomplished by removing a rubber band and separating the bundle into loose sticks. This same approach can be suggested by pictures on the plasma panel; by appropriate key presses, a student can separate a depicted bundle into ten separate loose depicted sticks, and so on. Figure 4.2 shows three frames from this lesson. Notice that, at first, the picture precisely matches the abstract notation. As the lesson progresses, the pictures are gradually suppressed, and the student deals only with the abstract notation -- but the pictures can still be presented as "helps" if needed or requested.

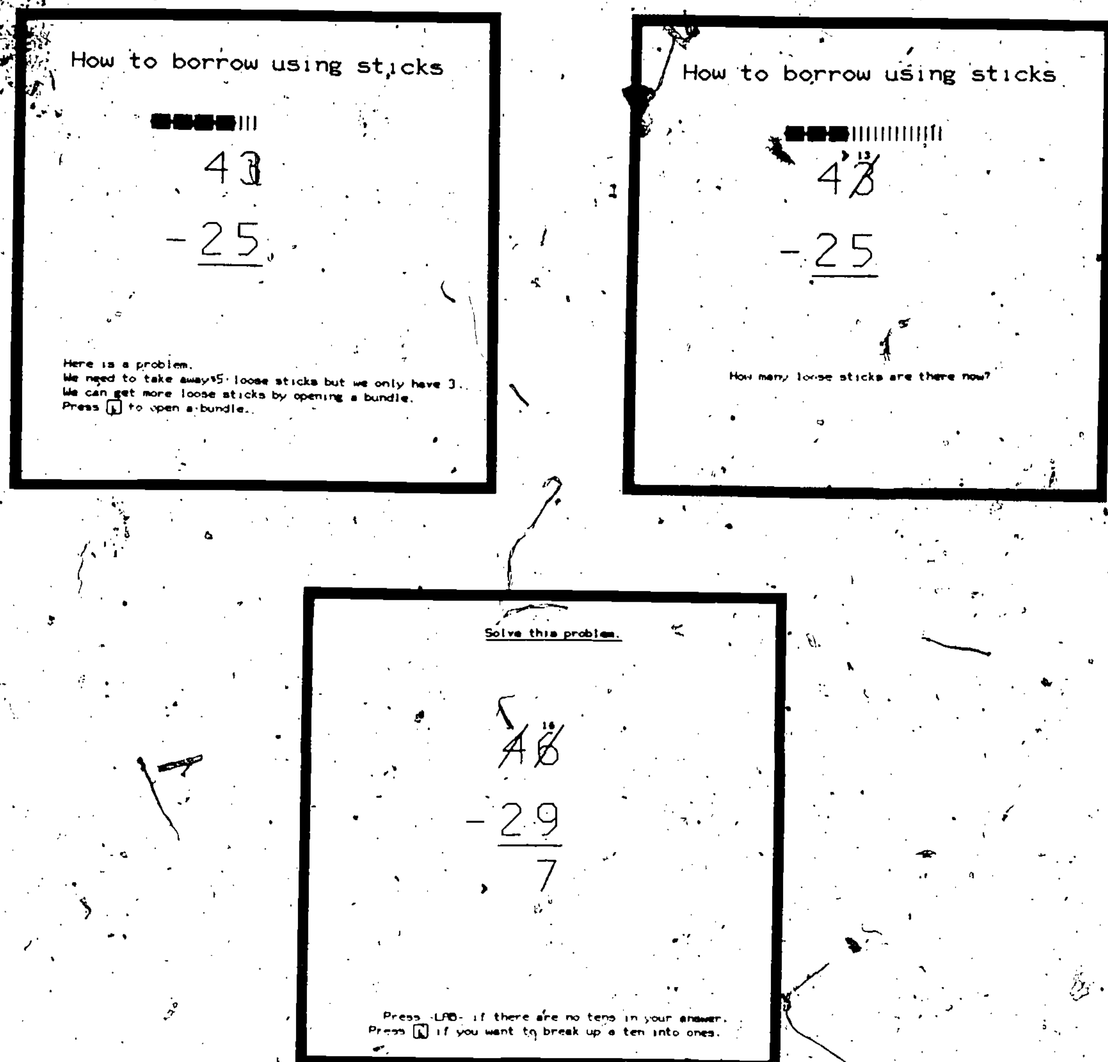


Figure 4.2. Three Typical Frames from the Lesson "Subtraction with Sticks"

PLATO can also present what Richard Suchman has called "a curriculum of starting points" -- as in the lesson "West," which introduces new ideas on strategy and on maxima without teaching either explicitly, and without continuing instruction on either. Here are opportunities for students to move ahead with these ideas -- and PLATO will continue to play its role if students do go on -- but there is no requirement that students do so. The lesson can thus be regarded as providing attractive motivation for drill and practice, or it can play the further role of introducing the student to some worthwhile new ideas. Two frames from "West" are shown in Figure 4.3.

It is critically important that students understand the meanings of mathematical symbols. In the case of fractions, for example, it is important for the student to recognize 7/8, or $3\frac{2}{5}$, or 5.4, as numbers having a definite size, just as 7 or 500 do. The graphics capability of PLATO allows the lesson designer to effectively address this problem. Figure 4.4 shows two displays from lesson "Darts" which illustrate this role.

PLATO can guide the student in learning tasks, and can provide subtle, controlled forms of feedback, as in the lesson "Sort Equivalent Fractions." If the student sorts one name incorrectly, PLATO tells him that one sorting decision was wrong, but does not say which one. The student thus faces the task of "de-bugging" his performance by a careful review of what he has done. Figure 4.5 shows three frames from this lesson.

The strategy of making displays appear (and change) at the same time as the corresponding abstract notations can be seen also in the lesson "Addition and Subtraction Practice with Simplifying and Borrowing," from the Fractions Strand. Figure 4.6 shows three frames from this lesson.

In classrooms without CAI, a student may exhibit a piece of work of which he is proud. Students also get ideas from the work of other students.

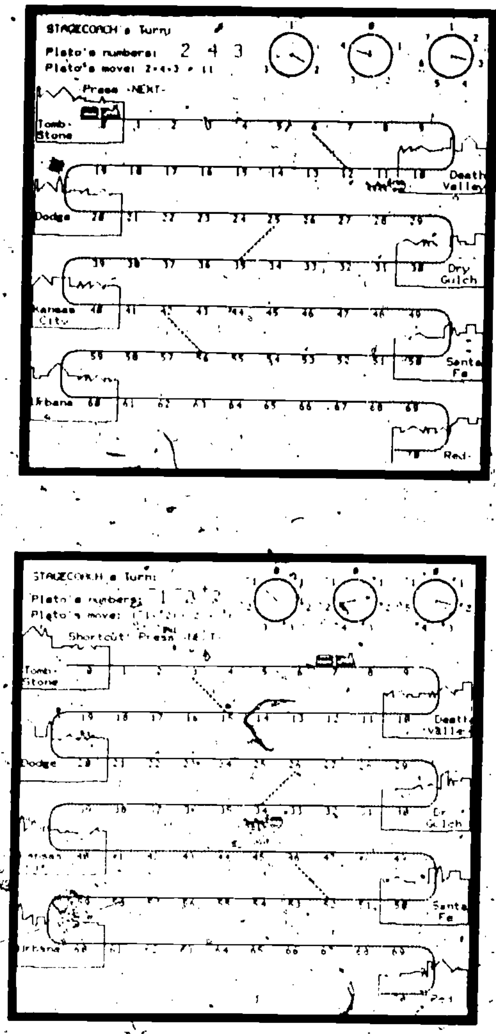
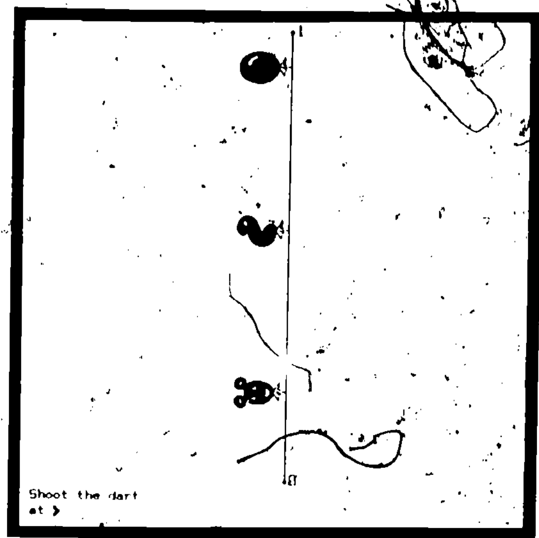


Figure 4.3. Two Frames from the Lesson "West"



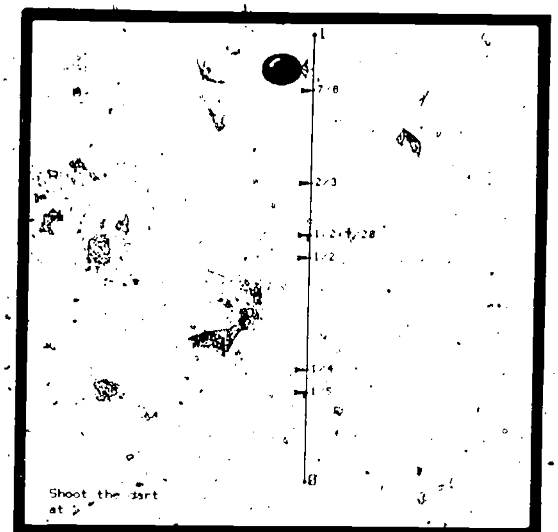


Figure 4.4. Two Frames from the Lesson "Darts"

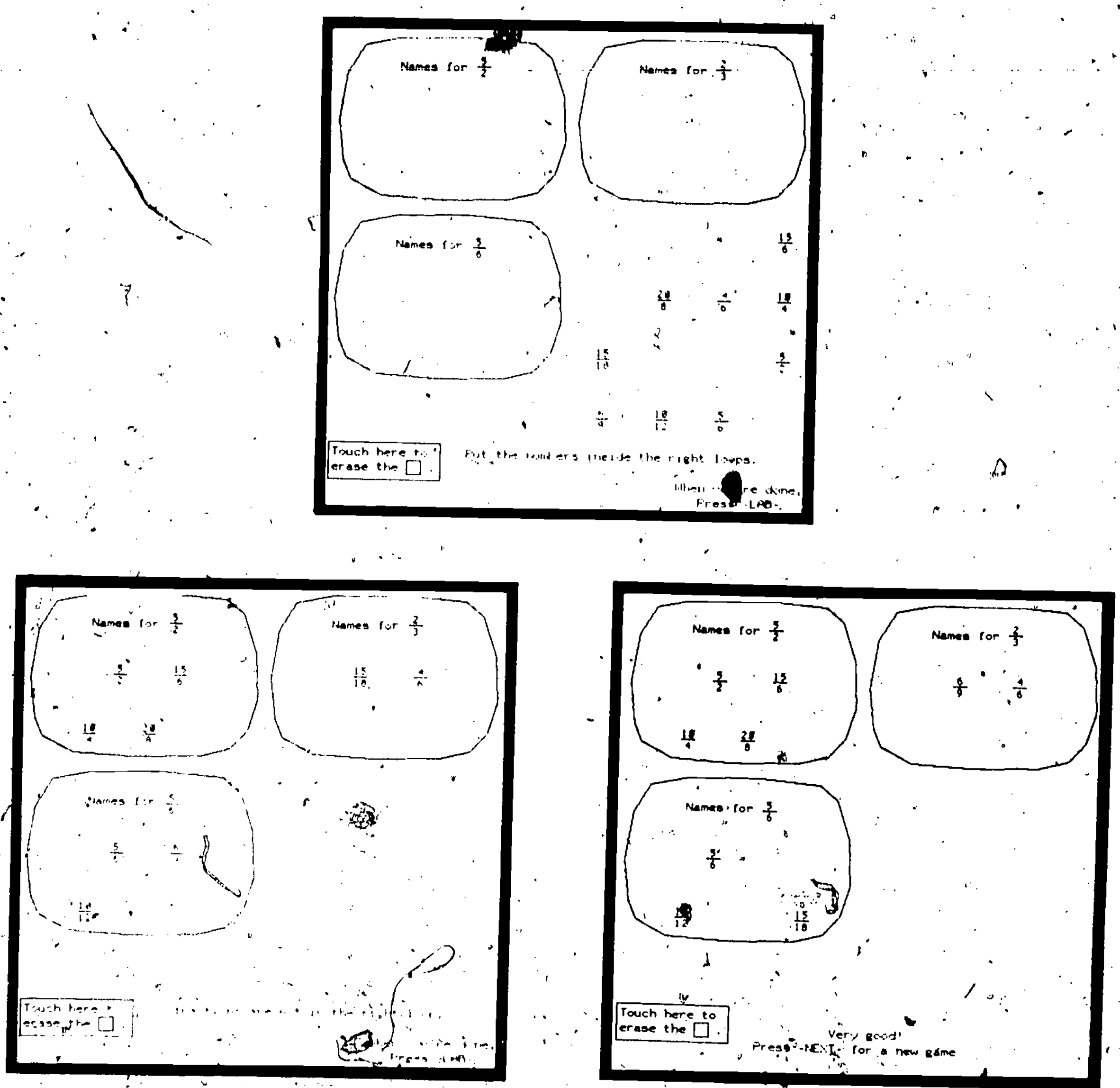


Figure 4.5. Three Frames from the Lesson "Sort Equivalent Fractions"

Purpose: Provide practice identifying equivalent fractions. This lesson is for students who already have a basic understanding of equivalent fractions.

Description: Several fractions are scattered on the screen along with 2, 3, or 4 loops. The student sorts the fractions into the loops so that each loop contains an equivalence set. If the student's solution is not completely correct, PLATO tells how many (but not which) of the fractions are in the wrong loops. The student must decide which of the numbers are out of place and move them. This causes the student to review his work and justify the equivalence for each number in order to locate the errors. Difficulty adjusts to the student's performance.

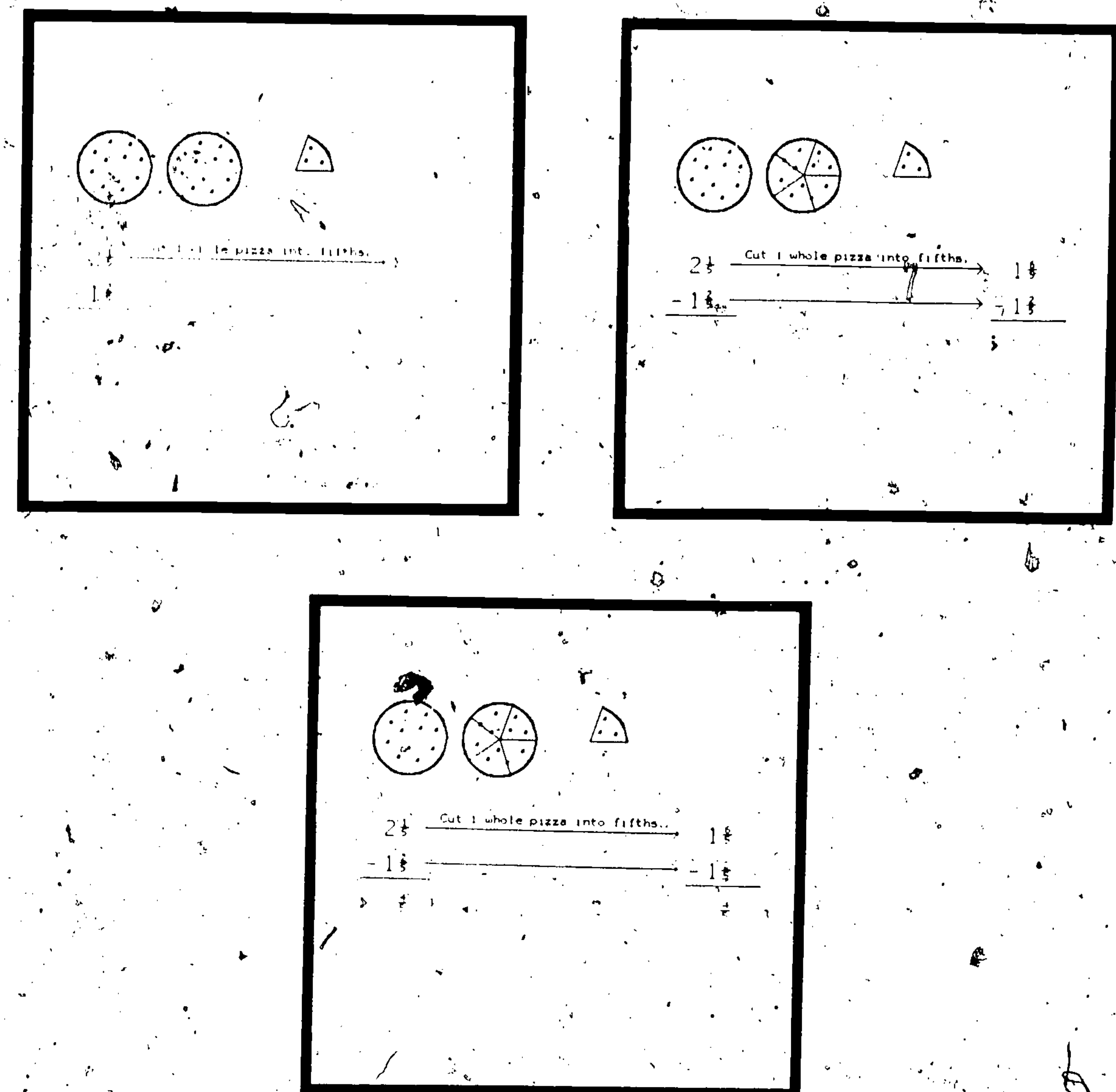


Figure 4.6. Three Frames from a Lesson on Adding and Subtracting Mixed Numbers

Both of these possibilities can be considerably enhanced by a suitable use of PLATO. One such use, designed by Dugdale and Kibbey, is the "paintings Library." In this lesson, a student chooses (or is told by PLATO) a fraction between zero and one. The task is to "color in" that fraction of a rectangle, using the touch panel to color (rather like finger painting, but with discretely quantized area). After PLATO verifies that the proper fraction of the area has been painted, the student may, if he wishes, add two of his paintings to a "library," stored in the computer's memory, that is available for other students to look at. An early version of this lesson did not provide this "library" feature, and the student work was rather uninspired. When the "library" was added, some very creative work began to occur, as suggested by the following sequence. The earliest solutions are usually relatively straight-forward, such as the drawing in Figure 4.7.

From sharing ideas, students come to see some more interesting possibilities, such as the painting shown in Figure 4.8.

In Figure 4.9 we see Lawston T. developing a new procedure for easy estimation of the area; and in Figures 4.10, 4.11, and 4.12 we see these ideas developed further.

Cynthia S. opened up some new possibilities, using her initials (Figure 4.13); this gradually led to further refinements (Figures 4.14 and 4.15), including a "contest" on the word "Hi!" (Figures 4.16 and 4.17), with variations (Figures 4.18 and 4.19).

The creativity, originality, humor, and pride displayed here is obvious, but the mathematical purpose has not been lost: in every case the student had to color a precise pre-specified fraction of the rectangle and he had to get it right before PLATO would allow him to save the painting in the "paintings library."

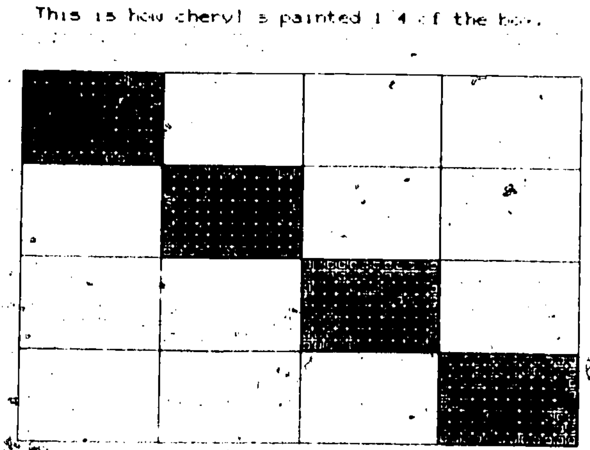


Figure 4.7. Cheryl S. painted 1/4 of the rectangle this way, and liked the result well enough to store it in the computer's "library" so that other students could see it.

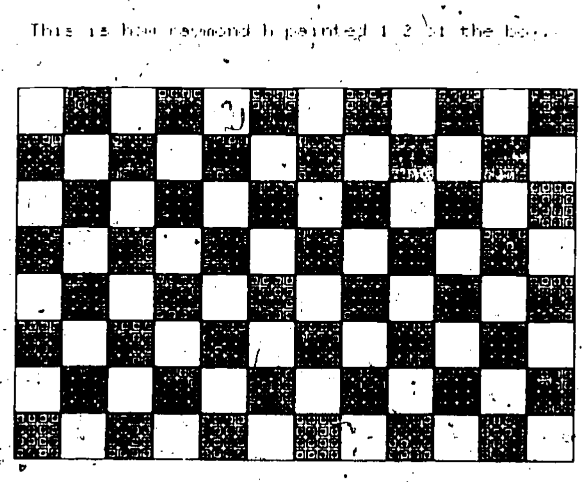


Figure 4.8. Raymond H. found an interesting way to paint 1/2 of the rectangle -- and to be sure that it is one half.

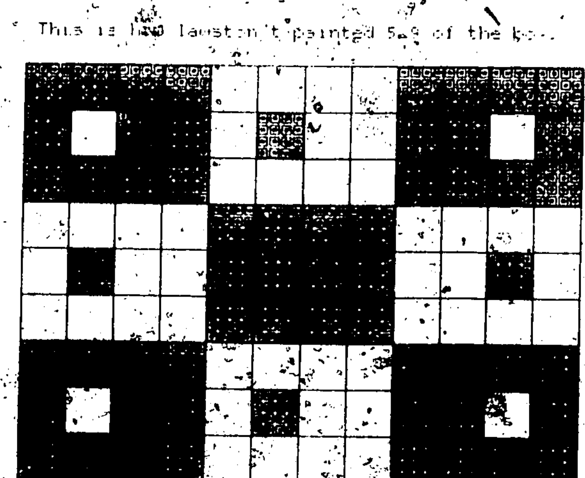


Figure 4.9. Lawston T. found a method for easy estimation of the fraction that is painted, yet at the same time allowing for more interesting artistic patterns.

This is how fred d painted 1/2 of the box.

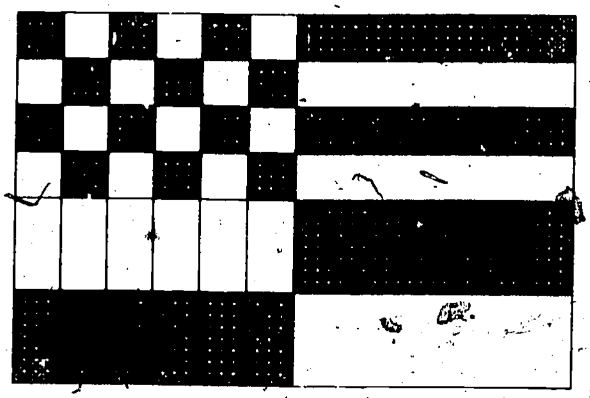


Figure 4.10. Lawston's method can be extended. Since Lawston's painting is in the computer's "library," other students can see it, be inspired by it, and carry the idea further -- as Fred D. has done in this example.

This is how frederic m painted 1/2 of the box.

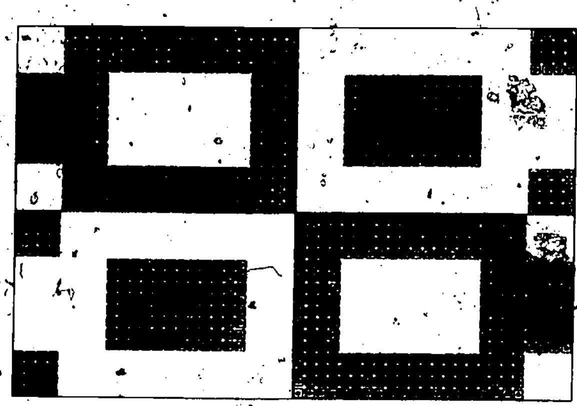


Figure 4.11. Some excellent artistic possibilities open up. Note that Frederic M. has painted exactly 1/2 of the rectangle.

This is how matthew h painted 1/2 of the box.

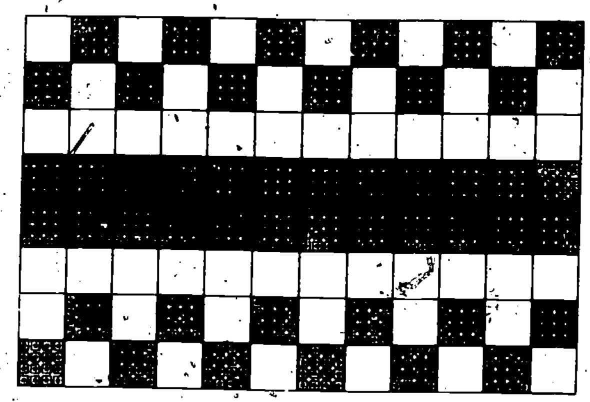


Figure 4.12. An interesting extension of Lawston's method.

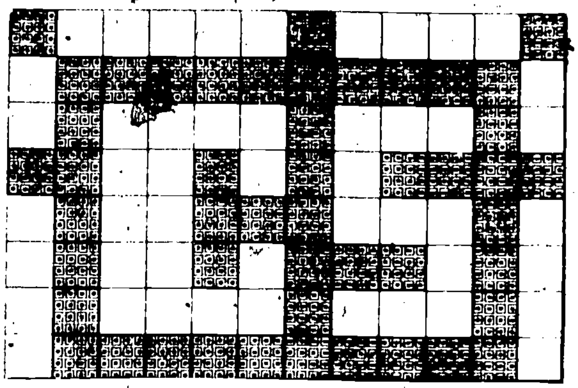


Figure 4.13. Cynthia S. had the idea of displaying her initials -- again in the computer's "library" so that other students can see it.

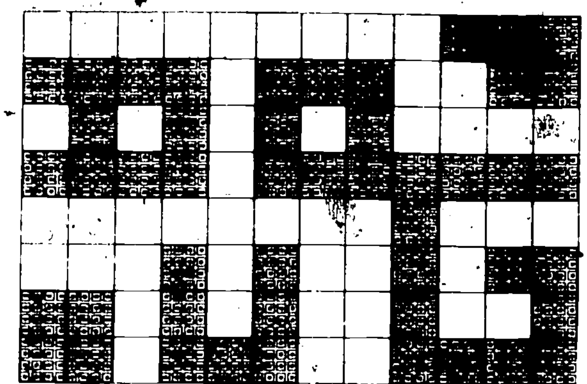


Figure 4.14. Cynthia's idea inspires another student to design a particularly artistic version of the name Doug. Exactly half of the rectangle has been painted.

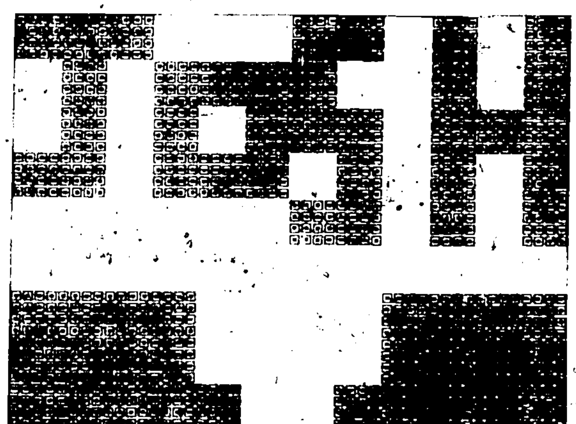


Figure 4.15. ...and a very attractive "Josh" (by Joshua P.) -- exactly 5/9 of the rectangle has been painted.

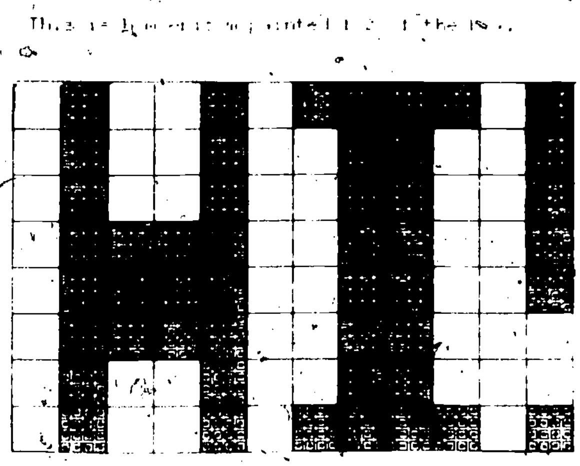


Figure 4.16. One entry in the "Hi" contest -- exactly half of the rectangle has been painted.

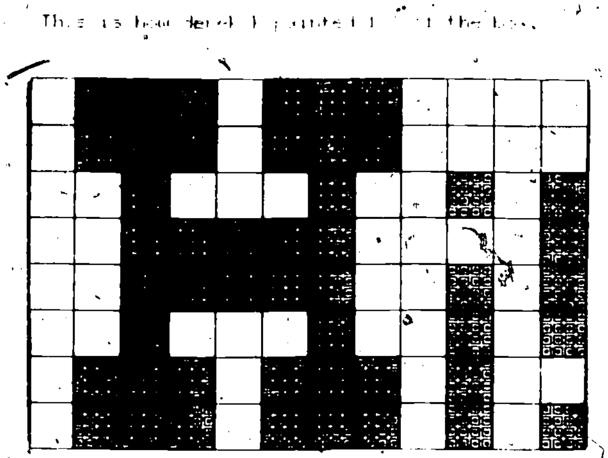


Figure 4.17. Another "Hi."

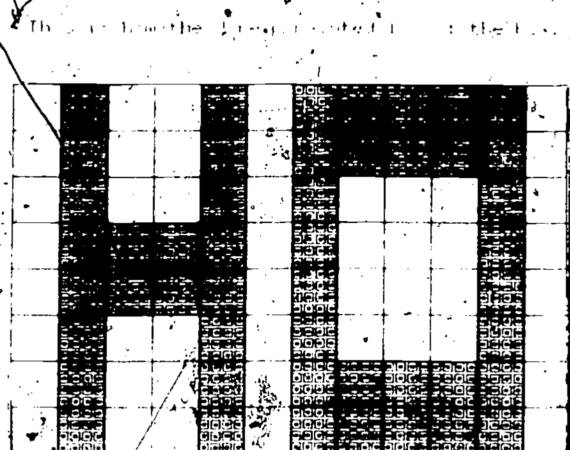


Figure 4.18. Time for a change. Exactly half of the rectangle is orange.

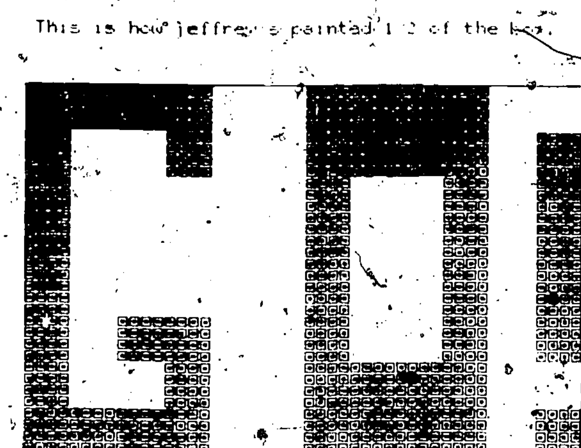


Figure 4.19. Even seemingly mundane aspects of arithmetic can be creative -- exactly half of the rectangle is orange.

4.4 COMMUNICATIONS BETWEEN TEACHERS AND PLATO

4.4.1 Teacher Inputs to PLATO

While the software for elementary mathematics can plan a reasonable half-hour session for each child each day, based on individual past performance, even if teachers make no planning inputs, it is possible, and easy, for teachers to shape the PLATO program as they wish.

A teacher can make an assignment for each student, for each day. That is, she can assign John to work in the whole numbers strand on Monday, Wednesday, and Friday, beginning in the third module, and to work on fractions on Tuesday and Thursday, beginning with the addition of mixed numbers; she can assign Edna to work on fractions the first four days of the week, and to work on reviewing whole-number multiplication every Friday; and so on, with a different assignment for every student in the class. (Or, she can have everyone look at the first lesson on graphs next Monday, so the class can all talk about it together; then on Tuesday each student can go back to his own individualized program.)

A teacher can choose from among the existing modules (groups of lessons sequenced by a curriculum). For the 1976-77 school year she will be able to create her own modules, by grouping or sequencing lessons according to her own scheme. Intermediate between "choosing" or "creating" there will also be the possibility of taking an existing module and modifying it in various ways.

The teacher can specify either a "regular" or a "review" (abbreviated, and faster) version of a lesson.

And, of course, a teacher can change this assignment for a student whenever she wishes.

4.4.2 Feedback to the Teachers from PLATO

All reports on student performance are available to the teacher in two different forms: directly as displays on the PLATO screen, or else as "hard copy" (i.e., printed on paper by a printer). Updated reports are ordinarily issued once a week, but teachers can obtain reports more often if they wish.

There are two kinds of reports: module reports, that show the progress of each child in terms of modules, and individual lesson reports, that show the progress of each child in terms of individual lessons. Since a module is a group of lessons, the module report is a more coarse-grained or macroscopic report, and the lesson report is a more fine-grained or microscopic report.

Figure 4.20 is a reproduction of a typical hard-copy module report. Student names are fictitious, but the report is not unlike typical actual reports. An explanation of these symbols follows the figure.

Figure 4.21 is a reproduction of a typical hard-copy lesson report. Again student names are fictitious. By calling for a more "microscopic" look at individual key lessons within the Fractions Strand modules, the teacher has, as it were, "increased the magnification" from the module report discussed above. This offers a more minutely-detailed look at student performance. Because there are well over 100 individual lessons in the fractions curriculum, this report shows only a few key lessons from each chapter. A student's performance in these selected lessons is a reasonable indicator of that student's overall performance and progress in the Fractions Strand.

Course: elrick

✓ Fine

✓ Satisfactory

– Unsatisfact.

T Terminated

C Continuing

F Fast State

thru 05/20

	Graphs	Whole Numbers	Fractions	Daily Sched MTWTF
debbie	C	C	+ ✓ C	FFFGG
carrie	C	+ C	+ ✓ C	FFFGG
andy	✓ C	C	+ + C	FFFGG
jeff	C	+ +	✓ C	FFFGG
tammy	C	C	+ + C	FFFGG
billy	C	C	+ ✓ + + C	FFFGG
ray	C		+ ✓ ✓ + C	FFFGG
clif	C		+ ✓ + C	FFFGG
jerry	C	C	+ ✓ C	FFFGG
teresa	C	C	+ ✓ C	FFFGG
val	✓ C		+ ✓ + + + C	FFFGG
cathy	C	C	✓ ✓ C	FFFGG
daryl	✓ C		+ ✓ ✓ C	FFFGG
kathy	✓ ✓ C		+ + + + ✓ C ✓ T	FFFGG
robert	C	+ C	C	FFFGG
james	✓ C		+ + + C	FFFGG
sharon	C	+ C	+ C	FFFGG
marcelon	C		+ + + C	FFFGG
rob	C	C	+ C	FFFGG
theresa	✓ C		+ ✓ + + ✓ C ✓ C	FFFGG
tom	C	C	+ ✓ + C	FFFGG
al	✓ C		+ ✓ + + C	FFFGG
pres	✓ C		+ ✓ + + + C +	FFFGG
leslie	C	+ C	+ C	FFFGG
diane	✓ C	C	+ + C	FFFGG
larry	✓ C	+ – C	+ ✓ C	FFFGG
eva	C	C	+ C	FFFGG
johnnie	C	+ C	+ C	FFFGG
tony	C	C	C	FFFGG
stacy	C	C	+ + C	FFFGG

Figure 4.20. A Typical Module Report (student names are fictitious)

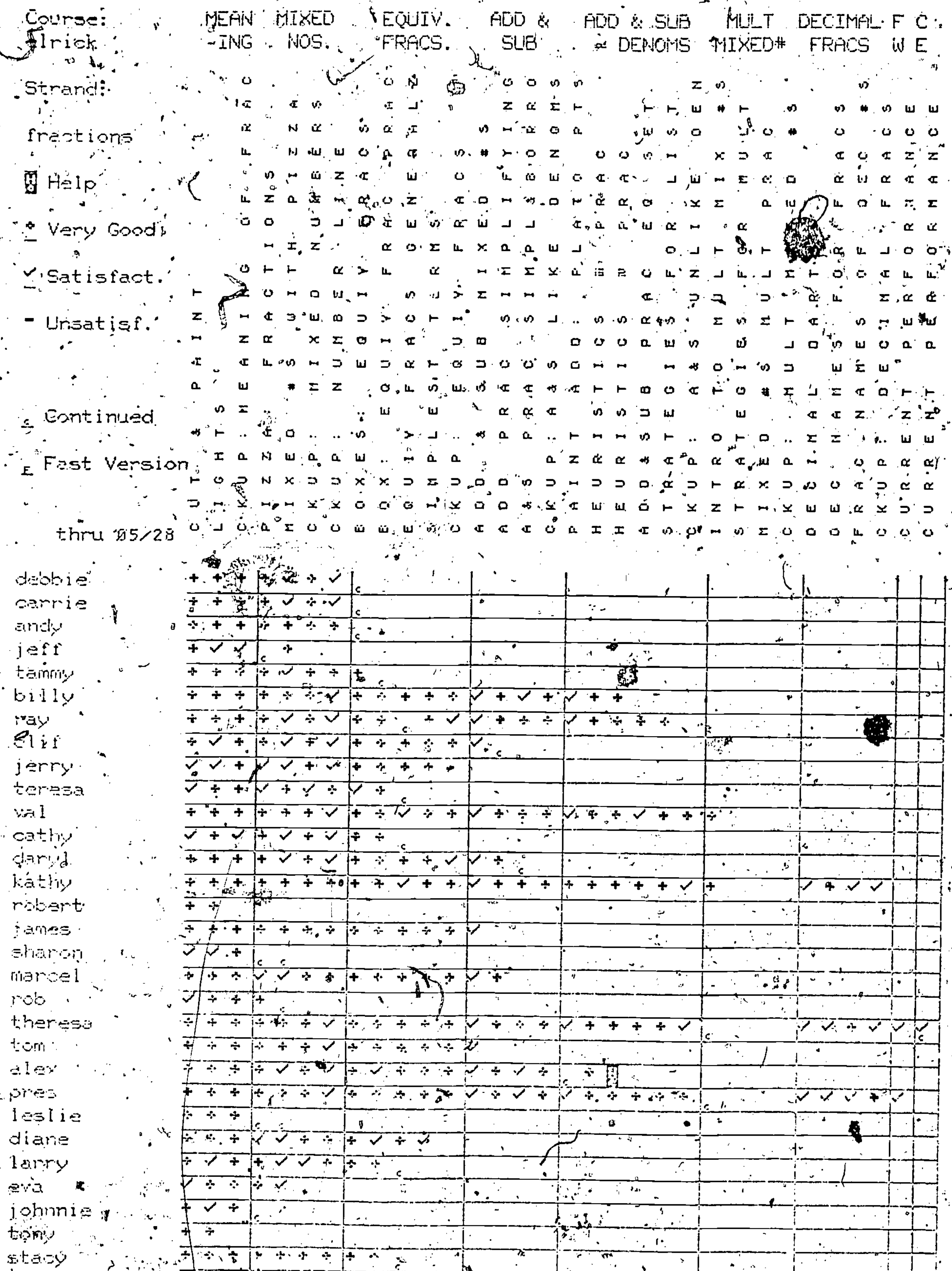


Figure 4.21. A Typical Lesson Report (student names are fictitious)

EXPLANATION OF SYMBOLS USED IN FIGURES 4.20 AND 4.21

Upper left:

+ indicates that a student has completed the module in question with excellent performance.

indicates that a student has completed the module in question with satisfactory performance.

\- indicates that a student has completed the module in question, but with marginal (less than satisfactory) results.

T indicates that the student did NOT complete the module because the teacher changed his assignment before he could complete the module (usually because he was not doing well in it, or else because it turned out that he knew that material already).

C indicates that the student is working in this module at present.

F indicates that the module is being experienced in its "fast" abbreviated review version.

Top of page:

Each standard module in each strand is listed (four modules for the graphs strand, five modules for the whole numbers strand, and nine modules for the fractions strand).

Right-hand column:

Column headings indicate Monday, Tuesday, Wednesday, Thursday, and Friday.

Column entries:

F indicates fractions strand
G indicates graphs strand
W indicates whole numbers strand

Thus, the first student listed ("debbie") has been assigned by the teacher to work in Fractions Strand modules on Monday, Tuesday, Wednesday, and Thursday, and on modules from the Graphs Strand on Friday, whereas Sta[illegible]ast name at the bottom of the list) has been assigned by the teach[illegible] work on Whole Numbers lessons every day in the week.

EXPLANATION OF SYMBOLS USED IN FIGURES 4.20 AND 4.21 (continued)

Center portion of page: Student progress in modules

The first student listed ("debbie") is presently working in the first module from the Graphs Strand, the first module from the Whole Numbers Strand, and the third module in the Fractions Strand. She finished the first fractions module with an excellent performance, and finished the second with a satisfactory performance.

"pres" (eighth name from the bottom) has finished the first module in the Graphs Strand (with a satisfactory performance) and is now working in the second module; he has never worked in the Whole Numbers Strand; and in the Fractions Strand, he has finished six modules (five of them with an excellent performance), is working on the module on "multiplying mixed numbers," and went through the first fractions module in its abbreviated (speeded-up) "review" version.

In general, symbols have the same meanings as in the "module" report, with one important addition: at the lesson level, a new symbol is introduced, $\boxed{\begin{matrix}H\\C\end{matrix}}$, meaning that the student is now working in this lesson and appears to need help from the teacher.

In Figure 4.21, one student appears to need immediate teacher attention, namely "al" (ninth name from the bottom of the student roster), who is presently working in two lessons: "paint add," where he does not need help, and "heuristics practice," where he does. Six other students in the class have completed this lesson very successfully, so the teacher might ask one of these six to work with Al, or else work with him herself.

4.5 HISTORICAL RECORD OF CLASSROOM TRIALS

Prior to September 1972, some individual lessons had been tried out, using PLATO III, in Booker T. Washington Elementary School in Champaign, Illinois. The terminal configuration involved a separate "terminal room," and students left their regular classrooms to come to the terminal room to work on PLATO.

Beginning in the fall of 1972, terminals were installed in two additional schools, and three different terminal configurations were subject to preliminary trials:

i) a separate terminal room

ii) terminals in the regular classrooms

iii) terminals in public access areas, such as corridors, libraries, and "learning centers."

It appeared that maximum benefit could be derived from terminals in classrooms, and this became the standard configuration for subsequent trials.

From Autumn 1972 until early in 1974, extensive "special testing" of lessons was carried out, but there was not a large enough body of courseware to make the use of PLATO entirely routine, and thus make possible what we have defined as "operational testing."

Operational testing of one strand -- the graphs strand, which was the first strand to be completed -- did become possible early in calendar year 1974, and in the spring of 1974 the graphs strand was in routine use in the experimental schools. Operational testing with a few students after school was done with the existing fractions curriculum. (About one-third of the planned curriculum was available.)

It had been hoped to begin operational testing of all three strands in the autumn of 1974, and something roughly approximating this did occur. The two major limitations were that the courseware for the other two strands had not yet been completed, and that unanticipated limits on computer memory severely restricted the number of lessons that could be made available to students at any given moment. A simplified router was written to try to optimize lesson assignment within these severe constraints, but it was all too clear that often PLATO could not make available to a student any of the lessons which he really needed at that moment.

Through all of these difficulties teacher morale remained surprisingly high, and informal measures of student learning gains seemed to indicate good results.

By September 1975 the limitations had been overcome: an adequate amount of computer memory was available, the necessary courseware had been completed, and the lesson-assignment procedures could work as intended. Consequently there was one year of official testing of this courseware -- September 1975 through May 1976. During this school year PLATO was in day-to-day routine use in thirteen classrooms, in six different schools, in two school systems. Four terminals were located in each classroom. Approximately 325 students participated, approximately as follows:

Grade 4	75 students
Grade 5	140 students
Grade 6	110 students

Over 15,000 student contact hours of instruction were delivered during this school year.

4.6 TEACHER AND STUDENT RESPONSE

This section deals mainly with informal measures and with preliminary results; for more formal results, and final assessments, please refer to the internal evaluation section of the present report (Chapter 3), and to the separate independent evaluation report from Educational Testing Service (ETS).

Teachers have responded enthusiastically to the PLATO elementary mathematics program, and so have the vast majority of students; informal preliminary reports seem to indicate important learning gains for students, and desirable changes in attitudes toward mathematics.

4.6.1 Student Attitude Changes

Attitude questionnaire data gathered by ETS from PLATO and non-PLATO classes in 1974-75 show relative changes in student attitudes toward math during the year that are favorable to the PLATO classes. Figure 4.22 shows results for the ten items on the questionnaire that were judged to be measures of general attitude toward math.

In Figure 4.22, "Math is fun" was item 14 in the questionnaire. Among the fourth graders, 43% of the PLATO students responded "yes" at the begin-

Figure 4.22
Attitude Questionnaire
Fall 1974 - Spring 1975 Data Summary
Percent of "Yes" Responses by Item and Grade

Note: For some items, positive attitude is indicated by a "no" response; for these items, negative relative changes are favorable to PLATO. In the "Merit Index" column, + indicates relative changes favorable to PLATO.

	Grade 4					Grade 5					Grade 6				
	Pre	Post	Chng	Rel. Chng	Merit Index	Pre	Post	Chng	Rel. Chng	Merit Index	Pre	Post	Chng	Rel. Chng	Merit Index
P*	N=47	N=49				N=97	N=111				N=125	N=126			
non-P**	N=68	N=71				N=92	N=90				N=89	N=95			
Liking or disliking math:															
14. Math is fun.															
P	43	55	+12	+17	+17	50	63	+13	+17	+17	50	63	+13	+21	+21
non-P	54	49	- 5			64	60	- 4			34	26	- 8		
22. Math is my favorite subject.															
P	13	22	+ 9	+13	+13	32	37	+ 5	+16	+16	18	29	+11	+18	+18
non-P	24	20	- 4			47	36	-11			15	8	- 7		
18. I would rather do almost anything than math.															
P	26	16	-10	-14	+14	24	17	- 7	-13	+13	18	15	- 3	-12	+12
non-P	21	25	+ 4			14	20	+ 6			29	38	+ 9		
26. Mathematics is often very boring.															
P	53	29	-24	-20	+20	35	32	- 3	-11	+11	39	34	- 5	-13	+13
non-P	46	42	- 4			36	44	+ 8			52	60	+ 8		
Comparison with previous liking or disliking math:															
21. I like math better this year than I did before.															
P	40	63	+23	+14	+14	47	63	+16	+21	+21	55	59	+ 4	+ 4	+ 4
non-P	53	62	+ 9			52	47	- 5			34	34	0		
28. I liked math better when I was younger.															
P	43	27	-16	-19	+19	36	26	-10	-17	+17	30	22	- 8	-20	+20
non-P	35	38	+ 3			41	48	+ 7			46	58	+12		
Sense of one's own ability to do math:															
16. I am good at math.															
P	40	53	+13	+11	+11	44	60	+16	+29	+29	42	52	+10	+ 8	+ 8
non-P	35	37	+ 2			62	49	-13			34	36	+ 2		
20. I am slow at doing math.															
P	34	25	- 9	- 8	+ 8	16	14	- 2	- 7	+ 7	25	13	-12	-21	+21
non-P	35	34	- 1			15	20	+ 5			23	32	+ 9		
15. Math is the hardest thing I have to do.															
P	19	20	+ 1	0	0	12	10	- 2	- 5	+ 5	18	13	- 5	-12	+12
non-P	19	20	+ 1			11	14	+ 3			17	24	+ 7		
17. I get worried when asked to do a math problem.															
P	15	10	- 5	- 6	+ 6	8	5	- 3	-10	+10	14	9	- 5	-3	+ 3
non-P	15	16	+ 1			14	21	+ 7			24	22	- 2		

* PLATO classes
** non-PLATO classes

ning of the year to this item, and 55% did so at the end of the year, for a positive change of 12 percentage points. On the other hand, 54% of the non-PLATO fourth graders responded "yes" at the beginning of the year to the same item, and 49% did so at the end of the year, for a negative change of five percentage points. Thus, the relative change was 12 - (-5) = 17 percentage points in favor of the PLATO classes. The figures for the other grade levels and the other items may be read similarly. Note that, for some items, "no" is the favorable response and, hence, for these items negative relative changes are favorable to the PLATO classes. The final column ("merit index") for each grade level gives the relative change recoded so that positive numbers denote changes favorable to PLATO.

Of course, each of these relative changes is a difference of two differences of numbers that are rather unreliable to start with (since each questionnaire item is a "yes/no" type item), so no single relative change can be interpreted with confidence. But the results found across the three grade levels and the ten different items display an overall trend of remarkable consistency: of the 30 numbers, one is a zero, and the other 29 are favorable to PLATO. A number of simple non-parametric tests on both first- and second-order differences confirm that the results observed could scarcely have occurred by chance alone.

Of the 24 remaining items on the questionnaire, 11 were about more specific math-related attitudes (e.g., "I like to show people how to do math problems," "I like working on math with my teacher," "I like learning about graphs"); seven were about reading ("Reading is fun," etc.); and six were about other things ("I am a good singer," etc.). No consistent pattern of results was evident across the items of any of these other groups. Thus, not only do the ten items concerned with general attitude toward math show great consistency of results, but they stand out in this regard from the rest of the items of the questionnaire.

4.6.2 Teachers' Observations

PLATO teachers were asked to keep daily logs for ETS during 1974-75, and portions of two such logs were available at CERL at the time this statement was prepared. They indicate that teachers perceive PLATO as having a generally favorable effect on student attitudes, and that teacher attitudes were also generally favorable. For example, one teacher writes:

> This would be a good time to note the effect of PLATO on the children's attitude toward themselves, school, and math. For a couple of individuals who have had in times past -- according to other teachers -- difficulties being happy in school and wanting to be in school, PLATO has had a positive effect upon their attitude as I perceive it. They do like working on PLATO and as a consequence, I think, do not want to jeopardize their position in the classroom. I also find that [now] there is nobody who dislikes math to the point of refusing to do it or finds it a total bore. I think PLATO has had some influence here.

All of our informal contacts also indicate that students like to work on PLATO, and that a desire to have extra sessions is far more common than a desire to avoid sessions. For example, when PLATO had been in one school for two weeks -- ten school days -- some students had completed 48 half-hour sessions. PLATO allows each student only one half-hour session during the school day, so the most time that any student could have spent during regular school hours would have been ten half-hour sessions. The remaining 38 half-hours were done evenings and weekends. The observation that "a desire to have extra sessions is far more common than a desire to avoid sessions" can be supported by considerable quantitative data.

Another teacher, after spending several pages describing PLATO's positive effects on her students, concludes by stating her own attitude toward PLATO:

I think PLATO is great! I hope to remain in the program.

If we ever go to "PLATO rooms," I would like to work with PLATO and children on a full-time basis. I wish that more children could have use of the terminals.

Another indication of teacher acceptance is that in over four years none of the 15 teachers left the program because of disatisfaction with PLATO. A few left for other reasons (e.g., family moving, maternity leave, etc.) and one teacher left when she was assigned to an advanced class that had already learned the mathematics available on PLATO.

4.6.3 Achievement Tests

Achievement test data gathered by ETS from PLATO and non-PLATO classes consistently indicate that PLATO can be used effectively to promote the learning of mathematics in elementary school classrooms. For example, in both 1974-75 and 1975-76, PLATO fourth and fifth grade classes far outperformed non-PLATO classes on ETS's special achievement test on fractions. Further discussion of elementary math achievement data and experimental design is given in the internal evaluation section of this report (Chapter 3).

4.6.4 Case Studies of Gifted Children

To many observers an important outcome has been the conspicuous intellectual flowering of a small number of gifted students (e.g., a number of twelve- and fourteen-year-olds are now excellent computer programmers, and one student has distinguished himself by an independent development of the Argand plane, by age fourteen). This sort of development is dramatic to observe, and in view of a general neglect of gifted students, it is potentially very important.

4.6.5 Seventh Graders at University High School

More detailed data is available on 30 students admitted in September 1975, into two sections of seventh graders at University High School. Ten of these students had been in PLATO classes the previous year (sixth graders in the 1975-76 trials), and one had been a student in a special summer program conducted by PLATO staff members. All 30 took an initial placement test in mathematics; on this test, four students made perfect scores. Two of these were from among the ten PLATO "alumni," one had attended the special summer program, and one was from among the 19 "non-PLATO" students. Other student scores on the test ranged down to zero correct (for a non-PLATO student).

These numbers and the numbers for gifted students are too small for statistical significance, but they are typical of the informal data that give a very strong general impression that children are learning mathematics and are finding mathematics interesting via PLATO.

4.6.6 Requests from PTA's and Schools

Questions asked at local PTA meetings are, so far as we have been able to monitor them, 100% favorable -- such as "When will we get PLATO in Mrs. X's class?", "Why can't more of our students get to work on PLATO?", etc. Requests to participate continue to be received from principals and teachers. All of this is presumably evidence of the general acceptance of PLATO within the school community.

4.7 SUMMARY

It appears that, although initial introduction of PLATO into the classroom places additional demands on the teacher, teachers want to continue with the use of these terminals. (In fact, a growing number of principals and teachers are requesting terminals in their schools and classrooms.) For the most part, students enjoy PLATO enough for their enthusiasm to manifest itself in many ways (for example, in seeking additional time on PLATO, even outside of regular school hours). Despite the rough nature of preliminary trials while we were still in the process of getting ready, it is quite apparent that children learn mathematics effectively from PLATO.

4.8 PERSONNEL

The director of the elementary mathematics project and the editor for courseware has been Robert B. Davis. The courseware has been designed and implemented by the following persons: Bonnie Anderson Seiler, Esther Steinberg, and Charles Weaver for the Whole Numbers Strand; Sharon Dugdale and David Kibbey for the Fractions Strand; Donald Cohen and Gerald Glynn for the Graphs Strand. Glenn Polin was responsible for the routing mechanism used during this period. Programming has been done by Marilyn Bereiter, Tom Layman, Helen Leung, Steve Sheahan, Keith Slaughter, Jim Wilson, and many graduate assistants and student employees. Administrative assistants for the project were Mary Gober and Anne Vogelweid.

5. ELEMENTARY READING

5.1 INTRODUCTION

During the period from 1971 to 1976 the PLATO Elementary Reading Curriculum Project (PERC) pursued a program which included:

1. Development of a hierarchical tree of behavioral objectives which describes a sequence of skills hypothetically involved in the learning to read process.

2. Development of approximately 80 hours of instructional materials in support of these objectives.

3. Development of a Computer-based Curriculum Management System (CMS designed to interface among the current status of the student's performance data, the tree of objectives, available lesson materials, and the constrai of available computer space.

4. Articulation of principles of audio/visual sequencing and student interaction patterns which permit the development of successful lesson paradigms.

5. Development of several such paradigms on which were based dozens of exercises.

6. Development of computer-based teacher control and feedback routin including student performance data reporters and lesson prescription routi

7. Implementation of the instructional routines and services outline above in 25 classrooms with 52 terminals equipped with touch panels, slide selectors, and random-access audio devices.

8. Delivery of 17,000 hours of instruction to 1,225 kindergarten, first grade, remedial, and educable mentally retarded students.

The principal successes of this program are believed to be the following:

1. The enthusiastic acceptance by students and teachers of well-designed CAI as a normal part of daily instruction. Between the school years 1974-75 and 1975-76 the number of teachers participating in the program increased from 15 to 25. All teachers were volunteers.

Teachers and other observers have also reported that students in general are enthusiastic about interacting with PLATO reading lessons. Students who have experienced behavioral or academic trouble in the classroom appear to be especially eager to interact with the lessons. Positive acceptance of both teachers and students, however, is contingent upon the proper functioning of equipment and the appropriate selection and design of lessons. When those conditions are met, enthusiasm is high.

2. The design of successful lesson paradigms. Data show (see Appendix 5.1) that most students interact successfully with our lessons and that their performance improves with successive iterations of the same lessons.

3. The clarification of perceptions about what degree of lesson-routing decisions-making is optimally handled by the computer as opposed to the classroom teacher (see Section 5.6).

The major obstacles to successful development and implementation of sophisticated curriculum are perceived as:

1. Unreliability of the audio component of the hardware. A child receiving garbled or incorrect messages will interact with a lesson incorrectly. Since there is no on-line mechanism to indicate that the audio is not functioning properly in a given case (nor is such malfunctioning

obvious to an observer who is not listening to the messages a child is receiving through an auxiliary set of headphones), lesson designers were severely hampered in their efforts to analyze the flaws in a given lesson. The problem was compounded by the often random nature of audio failures.

Another obstacle connected with the audio device was the production of audio discs. Because the implementation was large, requiring the production of about 50 copies of each disc made, and because of the unreliability of the disc production process, each disc had to be listened to in its entirety before being released to the classroom. A great deal of curriculum development staff time was spent engaging in this verification process, which takes about 20 minutes per disc. Student help provided for this task was insufficient.

The cumbersomeness of this process also discourages lesson revision, since each time a lesson was revised messages would be changed and new discs taken to the classrooms. Finally, the slowness of disc production frequently held up the delivery of lessons to the classroom to the extent that the objectives which the lessons were intended to teach had already been covered by the teacher.

2. Inappropriateness of the computer-based Curriculum Management System (CMS) to the realities of elementary classroom instruction. Although appearing to be sound in its initial conception (see Section 5.6) CMS in the final analysis acted against the integration of higher-level phonics and comprehension lessons into the curriculum (see below).

3. Scope of the original conception. In the opinion of most staff members, energy might have been better spent focusing on specific problems which showed promise of being unqiuely impacted by PLATO, rather than attempting to produce a complete curriculum on-line at a time when no guidelines for the use of PLATO with young children existed.

5.2 BACKGROUND AND GOALS

In 1971 the initially small staff of the PLATO Elementary Reading Curriculum Project (hereafter called PERC) set out under NSF Contract C-723 to develop a beginning reading program for young children to be presented on the PLATO IV terminal and tested in the public schools.

This enterprise began in a context which supported the image of the large CAI system's potential for taking over complex instructional decisions and tailoring instruction for individuals more sensitively than could the classroom teacher given limited time and large numbers of children. The hope was that, relieved of such bookkeeping tasks as recalling the status of children's skills and choosing appropriate lessons, teachers could devote more time to personal interactions -- developing children's social skills, dealing with the emotional and behavioral difficulties which increasingly plague the classroom, and engaging in the kind of instruction which can best be delivered face-to-face in free exploration of concepts and ideas.

For these reasons, it was decided early in the project to develop not only a set of lessons but also an automated system of selecting appropriate lessons and delivering them to students. This system would have the potential of standing alone, operating effectively without the intervention of the classroom teacher. At the same time, PERC staff members wished to offer teachers the option to design their own lesson sequences.

In pursuit of its mission, the Elementary Reading Group explored both automated and teacher-controlled systems, as well as many other aspects of real-world implementation of CAI. What follows is a statement of PERC's goals as they were perceived at the outset of the project, together with a discussion of how some goals were accomplished, some transformed in the context of classroom realities, and others left unattained because of technical difficulties or conceptual contradictions within the goal itself.

First, the PLATO Elementary Reading Curriculum Project was responsible for the development of a large body of instructional materials for beginning readers at the elementary school level.

Second, and growing out of the first goal, PERC was responsible for development of guidelines for child-computer interactions that would be both valid and general. By describing rules of thumb about display organization and response processing, PERC could reduce the amount of start-up overhead for future such curriculum projects.

Third, PERC was responsible for development of a reasonable model of the learning-to-read process.

Fourth, PERC was responsible for construction of a beginning reading curriculum integrating individual activities within the scope, sequence, and logical structure of the learning-to-read model.

Fifth, because PERC was pioneering the large-scale classroom implementation of computer-based curricula, another responsibility was to explore alternative ways of integrating the computer-based activities into the culture of the classroom.

Sixth, PERC saw as its responsibility the development of a computer-based curriculum management system which would interface between the instructional materials and the reading model on the one hand and the constraints of the PLATO system on the other. To allow freedom to experiment with different structures and at the same time to permit maximum independent functioning, this system would need to be flexible as well as powerful, permitting the teacher to override the structures managed by the automated routing system.

Seventh, related to PERC's commitment to experiment with alternative forms of classroom implementation, was a responsibility to develop a powerful system whereby teachers could access on-line performance data for individual children and groups of children.

The sections which follow treat these goals in greater detail.

5.3 LESSONS

The commitment to develop a large body of instructional materials in beginning reading has resulted in the production of approximately 80 hours of lessons. Below is a listing of lessons available by category, together with a brief description of the contents of each.

5.3.1 Orientation to the PLATO Terminal

This category includes 14 lessons aimed at familiarizing the child with how to interact with the terminal: how to type his or her name on the keyboard, how to use special keys, and how to use the touch panel. These lessons also provide the child with a chance to become accustomed to wearing the earphones, changing audio discs, and listening for directions. This preparation is important to the child's competent functioning in reading skill-oriented lessons. Most of the lessons make heavy use of animations and imaginative situations with which the child can interact.

5.3.2 Visual Skills

This category includes 35 lessons intended to exercise children's visual discrimination of letters and words, and also to expand their visual memory. Lessons include exercises in matching of letters and words from fields of closely similar as well as dissimilar foils. Exercises in discriminating rotations and reversals of letters and words are also presented.

5.3.3 Letter Names, Alphabetization, and Introduction to Letter Sounds

This category contains over 40 lessons teaching letter names, introducing letter-sound associations, and offering exercises in alphabetization and the matching of lower-case and capital letters. The lesson formats include games and animated presentations as well as interactive exercises.

5.3.4 Auditory Discrimination

The auditory discrimination category contains over 110 lessons devoted to teaching and exercising skills in detecting the presence of a given phoneme in the context of words. Instruction often occurs in the setting of a game in which the child interacts with an animated character.

5.3.5 Phonics

This category contained approximately 50 lessons devoted to teaching letter-sound correspondences. Most of the lessons were in a drill and practice format. Programming problems, plus the unpopularity of the rather dry presentations, necessitated the early disabling of these lessons.

5.3.6 Basic Vocabulary Words

This category contains approximately 70 lessons which teach and drill about 56 common words, most of which are not decodable with straightforward rules of letter-sound correspondence. Lesson formats include such games as "Snap" and "Bingo," interactive models such as an elevator that responds to appropriate touches on the words "up" and "down," and the construction by the child of interactive stories using the words he or she has learned.

5.3.7 Concept Words

This category contains twelve lessons which give the child experience with the concept represented by a given word as well as the written form of the word. Lessons are in the form of animated illustrations and interactive models.

5.3.8 Stories

This category contains over 30 stories which fall under three different headings:

1. Touch-sensitive commercial stories. These stories, used with written permission of the publishers for experimental purposes, include a selection of the finest children's trade books available. Children can read the stories by themselves or can request the computer to read them page by page, sentence by sentence, word by word, or any mixture of the above simply by touching the appropriate place on the screen. The texts of the stories are accompanied by their illustrations projected on the screen through use of the random-access slide selector.

2. Pacer stories are delivered without audio and are accompanied by comprehension questions. Although past versions of pacer stories presented stories to children line by line at a preset pace and width, the present version allows the child to control the pace at which the story appears. At the end of a story, the student is informed how fast she or he has read the story and is given a score on the comprehension questions. The purpose of these exercises is to increase the speed and accuracy of the child's reading.

3. Interactive stories. These stories allow the child to choose, at certain crucial points in the plot, among a number of alternatives which

cause the story to take a given direction. The stories are intended to improve a child's perception of a narrative as consisting of component parts which the author manipulates. It is hoped that interaction with such stories at an early age would lead to improved skill in written composition and in perception of causal chains in narrative.

5.3.9 Miscellaneous

This category includes such activities as a "start the day" routine which teaches calendar concepts, plus special displays for holidays and children's birthdays.

5.3.10 Lesson Implementation

These lessons have been tested over a three-year period with a total of 1,225 kindergarten, first-grade, and second-grade children, together with a few classes of remedial and EMH students. (See Table 5.1.)

Although we soon realized that it was unrealistic to expect busy primary teachers to learn to program their own lessons, or in most cases to write lesson specifications complete enough for a programmer to work from, still a few teachers did sketch quite a respectable number (50 at least) of lesson ideas which showed promise of usefulness on PLATO. Unfortunately, PERC's early dreams of using teachers as a major source of lesson ideas failed to be realized because of a lack of programmers sophisticated enough to write lessons based on their ideas and because the rich nature of many of these activities conflicted with the incapacity of CMS, unanticipated by its designers, to integrate higher level activities with activities developing isolated skills.

TABLE 5.1

SCOPE OF IMPLEMENTATION

In 1972-73 and 1973-74, small numbers of students participated in the experimental development of lessons. No terminals were installed in classrooms.

	Feb-June 1974	1974-75	1975-76
Number of Classrooms			
Kindergarten	1	1	5
Kindergarten-First	1	2	3
First Grade		3	9
First-Second Grade		1	
Second Grade		2	2
Remedial		5	5
EMH (9-11 years old)	—	1	1
Total Number of Classrooms	2	15	25
Number of Schools	1	8	9
Number of Terminals	4	29	49
Number of Teachers	2	15	25
Number of Children	75	400	750
Number of Student Contact Hours	1,000	6,000	10,000

Despite lack of heavy teacher input to lesson design, teachers were eager to use our materials. Their chief interest lay in the lessons' capacity to hold the children's attention, to allow the children to interact comfortably, to generate enthusiasm for reading, and to teach necessary skills and concepts. Their most frequent demand was for additional lesson materials.

Whether lessons were managed under the automated curriculum management system or under the teacher-controlled management system (see Section 5.6), all lessons shared certain features. Lessons were kept short (averaging about three minutes) and highly interactive, demanding a response from the child at least every ten seconds. In addition, children have the option at the end of a lesson to do the lesson again or to go on to another lesson.

Generally speaking, children received PLATO instruction once a day for one fifteen-minute session. Depending upon the structure of the classroom, the session might occur during the child's regular reading period or some other time during the day when the child was free.

5.4 GUIDELINES FOR INTERACTION

From the beginning PERC staff members devoted a great deal of time and energy to the development of paradigmatic lessons which would allow a six-year-old to interact with the terminal competently and independently, while at the same time focusing on the skill to be learned. Typically, development of such paradigms followed a pattern of initial programming founded on the best estimate of successful design, followed by repeated revision on the basis of close observation of children working through the lesson in a classroom setting. Once direct observation coupled with lesson performance data showed a design to be successful, the design principles could be abstracted and applied to the development of more lessons built on those principles. Additional exercises were also added to specific models. For instance, in the auditory discrimination strand, forty exercises were generated on the basis of the initial paradigm.

This close attention to lesson design has contributed to one of PERC's successes. Six-year-old students have few troubles interacting with PERC lessons and they usually achieve the criterion level set by each lesson. Moreover, they like the lessons and remain eager to work on the terminal.

To summarize the approach which PERC has found most successful, lessons are designed as nearly as possible around the principle that students want to be effective within their environment; in other words, they want to make the terminal "work." PERC thinks of the student as providing the stimulus and the terminal as giving the response rather than the other way around; for example, students put words together to form a sentence (stimulus), and the terminal animates the sentence (response).

Obviously not all lessons can be designed to give the student the feeling of full control over the lesson; but most lessons do conform to the following guidelines, which promote the student's sense of control over the lesson:

1. PERC lessons are highly interactive and require a response about every ten seconds.

2. Interactions are kept as "meaningful" as possible; that is, the interaction is focused around the skill being learned.

3. Remediations are kept to a minimum. Complicated remedial loops can be perceived by students as reinforcing because such loops produce interesting screen displays; therefore, when a student makes an error, he is simply told that he is wrong and advised how to get it right.

4. Procedural errors (errors made out of carelessness) are simply ignored for the reasons described above. When the students make a response which is neither right or wrong, and when the terminal fails to respond to them, students usually correct themselves quickly.

5. Reinforcers are faded; elaborate reinforcements (such as audio messages and long visual displays) can interfere with the interactive pace of a lesson.

There are three comments to be made about the above guidelines:

1. Not every lesson conforms to every guideline; there are useful instructional strategies which fall outside these guidelines.

2. An entire sequence of lessons which violated most of those guidelines was present in the 1975-76 curriculum; by all measures, those lessons failed.

3. The guidelines work well with PERC's first grade population; however, there is some evidence to indicate that first semester kindergarteners had difficulties interacting with PERC lessons, largely because of the younger children's need for more prompts.

One of the thornier problems that has plagued PERC has been developing lessons in which the interactions were simpler than the skill being learned. This difficulty to a large degree stemmed from PERC's commitment to produce an entire beginning reading curriculum on-line. Our experience leads us to believe that it would have been better if PERC had produced primary instruction only on those skills which could be taught in a unique way via CAI and if lessons had been developed specifically to complement the classroom teacher's primary instruction.

5.5 MODEL OF THE LEARNING-TO-READ PROCESS

Early in the project staff members developed a model of the learning-to-read process, a structure which was intended to bring to the curriculum clarity of goals, a means of diagnosing reading difficulties, and a standard by which to measure the success of various lesson strategies. (See Appendix 5.2.). The structure was based on the premise that, for the purposes of teaching and evaluation, reading can be defined in terms of observable, measurable behaviors, that the acquisition of some of the behaviors is prerequisite to the acquisition of others, that some behaviors may be acquired independently of others and that the detailed, explicit statement of these behaviors, their order and interrelations, provides a sound structure for a computer-based system of teaching reading and diagnosing reading difficulties.

The result was a hierarchical description of a hypothetical process of the acquisition of reading skills. Subsequent experience in the meshing of the hierarchical structure with specific lessons and the management of the resulting curriculum by an automated system, however, leads us to believe that a hierarchical description of needed skills is not sufficient to manage instruction efficiently. We will delve further into this problem in the discussion below, which deals with the interrelated problems of curriculum development, management, and implementation.

5.6 CURRICULUM DEVELOPMENT, IMPLEMENTATION, AND MANAGEMENT SYSTEMS

PERC's experience with building a computer-based curriculum and the impact of decisions relating to the management of that curriculum upon classroom implementation can hardly be discussed separately. Having conceived of the curriculum in terms of hierarchically related skills, PERC staff members developed and implemented the Computer-based Curriculum Management System (CMS) which was designed to dynamically route students from lesson to lesson on the basis of performance data gathered on-line. It was the intention of the designers that CMS obviate the necessity of frequent and time-consuming teacher intervention in the lesson selection and delivery process and also that CMS provide more continuous attention and sensitive decision-making for each student than could the busy classroom teachers. (See Appendix S5.1[1]).

In some ways, CMS fulfilled its task admirably. In the beginning of the school year 1975-76, 700 students received daily instruction delivered by CMS with few failures and little or no outside intervention. In a context in which students were receiving substantial instruction from no other source, CMS might have operated reasonably satisfactorily. As it was, in the primary classroom the first concern of teachers and students is the gaining of competence in reading. Indeed, most primary teachers consider themselves first and foremost to be teachers of reading. Hence, they typically use a considerable variety of means to teach reading, and directly or indirectly devote the majority of the school day to this pursuit.

In the face of such redundancy, student performance data gathered on-line rapidly became obsolete. Over time, the gap between what the student knew and what CMS thought the student knew progressively widened, until finally the quicker students became bored with the lessons they were getting. Unfortunately, CMS offered no simple, clear, and reliable way for teachers to change lesson sequences, despite great efforts to integrate a teacher-managed system into the computer-managed system. Just who was in control of lesson delivery was ambiguous, and the prescribing process difficult and unreliable.

[1] J. Risken and E. Weber, "A Computer Based Curriculum Management System, Ed. Tech. September 1974 pp 38-41.

A second problem arising from the operation of CMS arose from the hierarchical description of the curriculum structure, discussed earlier. Neither the structure nor CMS allowed for defining critical "horizontal" relationships in instruction. For instance, it is trivial to stipulate that a student be able to associate the phoneme /a/ with the grapheme "a" before decoding words containing that letter-sound correspondence. The real difficulty lies in deciding upon what strategy to use to teach this correspondence. That decision is based more on what specific words and letters the child already knows than on what general skills have come before (the vertical relationship). From this illustration, it is also clear that decision algorithms for sequencing lessons are unique to each skill area; a generalized decision-maker is not useful for selection and sequencing of specific lessons.

Naturally, the lessons and curriculum management options available will affect the form of implementation, since these options determine whether and how easily the computer-based curriculum can be integrated into on-going classroom activities. The discussion which follows will clarify some of these relationships.

Early in the project, PERC staff members decided that the most promising configuration for PLATO terminals in the primary grades lay in individual classrooms rather than in rooms set aside exclusively for CAI. In part, this decision was based on technical limitations. More importantly, it was intended to assure that PLATO technology became a familiar, frequently used, and highly accessible resource, and that it not be relegated to the status of "frill" like music or library.

This model of implementation has obvious drawbacks: for instance, responsibility for supervising children on PLATO and for reporting machine and courseware malfunctions falls on the teacher rather than on a terminal room monitor. Nevertheless, locating terminals directly in classrooms has proved to be highly popular. Of the twenty-five teachers involved with PERC, none has requested that terminals be removed from her room, and all are enthusiastic about keeping terminals in the future.

Questions about the educational uses of PLATO-delivered instruction are more difficult to resolve. From the beginning, staff members were concerned that PERC be easily usable for mainline instruction, review, reinforcement, or enrichment as the teacher chose. Unfortunately, the design characteristics of the curriculum and of CMS as outlined above hampered efficient teacher control and discouraged attempts at integrating on-line and off-line instruction.

For these reasons, and despite initial success, CMS was put aside during the last four months of the PERC project and a new system was substituted. The new system is a simple router which allows teachers to design a sequence of activities to be delivered to a specified student, group of students, or an entire class. The router then delivers lessons to the students in the order which the teacher has designated.

This strategy is a complete reversal of the CMS experiment. Responsibility for curriculum management shifts from the computer and those sophisticated in its manipulation to the classroom teacher. Not surprisingly, given clear, unambiguous, and easy control of lesson sequencing, teachers began to take a greater interest in PLATO reading lessons and in how these lessons might be integrated into classroom instruction.

The resulting individual lesson sequences often might not appear to the outside observer unfamiliar with the needs of specific individual children to have the consistency and coherence of a portion of "curriculum."

This apparent inconsistency stems directly from flexible use of lessons. For instance, in one session, a child might receive an exercise dealing with the word family ending with -at, a story, and a sight word game. These activities may appear to be unrelated to one another, but in the context of other classroom activities, they take on more meaning: the word family exercise might act as an introduction to an off-line teaching sequence, the story as enrichment, and the sight word game as a review of learning that took place several weeks earlier.

Thus only when teachers were put in full control of lesson sequences were they free to engage in alternative uses of PERC courseware. Reliance on PERC staff members to interpret and alter lesson sequences dropped to practically zero; PERC site supervisors were able to devote more time to observing and analyzing the quality of student interaction with lessons. At the same time, students received lessons more appropriate to their actual level of functioning, and both students and teachers expressed greater satisfaction with and enthusiasm for interacting with the system.

5.7 STUDENT PERFORMANCE DATA

A persistent concern of the PERC group has been to provide teachers with easily accessible, continuously updated student performance data. Throughout the 1974-75 and 1975-76 implementation periods these data were available both on-line and in hard-copy. On-line data were continuously available. Hard-copy printouts were available on request.

Teachers often made use of this data to recheck their own perceptions of a child's progress and to inform parents of a child's activities and problems on PLATO. A number of teachers sent home individual student performance printouts as auxiliary report cards. In one case, the information contained in the printout helped to convince a previously skeptical parent that a child needed extra help in a certain area.

Problems in reporting student performance data centered mainly around the questions of how to display data for an entire group or class on the screen at one time. The size of the screen and the amount of information to be shown made it virtually impossible to construct a visually uncluttered display. Nevertheless, the demand for a one-page whole-class data summary persists, and efforts are being made to design such a page.

5.8 HARDWARE AND SOFTWARE CONSTRAINTS

At this point it may be useful to discuss some hardware and software related constraints which impinged heavily on efforts to achieve the goals outlined above. It is against the background of these constraints that PERC achievements should be viewed.

First, one responsibility not directly related to educational goals and yet significant in its impact on PERC's achievement was the necessity to field test and contribute to the development of the random access audio device and to create software and hardware designs to produce audio discs. The design inadequacies of the early audio system, both production of discs and output of sound, resulted not only in delaying delivery of lessons to classrooms but also in complicating diagnosis of lesson design flaws based on teacher reports. These reports could not be taken at face value until it had been ascertained whether the problem was a design flaw in a lesson which was operating as intended or in an audio malfunction. If the difficulty did lie in badly delivered audio, staff members then had to discover whether the device in the classroom was faulty or whether the device which produced the disc was faulty. This distinction was further complicated by the fact that mastering machines and machines in the classroom were often not aligned to the same standard. As a result, machines could test out as mechanically reliable and yet not deliver adequate sound because they were playing a disc produced on a machine aligned to a slightly different standard.

• All these aspects of dealing with the audio device -- software design, hardware problems, recording of masters, mass producing discs, going out to schools to pick up faulty devices and deliver repaired devices -- took up significant amounts of staff time and energy and resulted in delayed or diverted lesson development.

Secondly, although the long-range tendency has been to facilitate lesson design and to reduce the number of programming hours required to get the lesson into working shape, the continuing evolution of system software has at times presented obstacles to lesson implementation. System software changes had unproductive consequences when altered or obsoleted commands caused previously operational lessons to fail and required programmers to bring their code into line with the new conventions. Greatly on the positive side, however, improvements in such areas as graphics have significantly reduced the effort that goes into display generation by making characters easier to design and manipulate and relative sizing, rotation, and animation of figures easier to accomplish. For example, the series of commands necessary to generate a simple moveable and sizeable box required 26 words of computer space in 1972. In 1976 improvements in commands brought that figure down to four words of space and greatly simplified programming procedures.

In addition to improvements in commands, systems features developed within the last year have broadened our communications options for both students and teachers. Groupnotes files now available for student use have allowed us to offer children the chance to type stories and news items into a file which can be accessed by other children using PLATO. The groupnotes option can also be used by teachers to communicate with PERC staff and with each other.

Moreover, new developments in Instructor Mode have expanded opportunities for teacher involvement in the PLATO system as a whole. Among the communications options previously not available to teachers are not only groupnotes files but also personal notes, which unlike groupnotes are accessible only to the person to whom they are addressed, and the "talk" option, which allows instant paging of and communication with anyone concurrently on the system. In addition, teachers can now directly access the "repair" lesson, which allows them to report hardware problems directly to maintenance personnel, rather than routing such complaints through the PERC staff. Finally, through the new Instructor Mode teachers can now perform their own roster manipulations and access any lesson on the PLATO system. All these developments, offered since February 1976, have contributed to teachers' involvement in the "culture" of the PLATO system and have reduced the amount of staff time that must be devoted to routine manipulations.

Although the system developments described above have reduced the amount of programming effort required to get lessons up and running and have expanded the range of modes of interactions with teachers, more work at the system level remains to be done if PERC is to concentrate its full effort on lesson development and curriculum design. Two crucial areas in which system support has not yet been provided are audio management software and expanded data structures and manipulation options. System support in the former area would free PERC programmers from having to maintain these programs; support in the latter would increase the "exportability" of our lessons by freeing them from dependence on data-base structures unique to PERC.

5.9 UNIQUE CAPACITIES OF PLATO IN READING INSTRUCTION

The experience of members of the PERC group over three years of active involvement with teachers and children points overwhelmingly to the high motivational effect of PLATO. Children who have experienced difficulty with or distaste for ordinary classroom activities typically engage willingly in PLATO activities. The majority of teachers involved have at some time produced desirable behavior in problem children by making their use of PLATO dependent on completion of other tasks or on appropriate social behavior.

We attribute PLATO's success in motivating children to the following characteristics:

1. The fact that the child controls the medium. Unlike a TV or record player, which operates without child activity once the device is turned on, PLATO remains passive unless the child provides input.

2. The variety of sensory stimulation. PLATO provides coordinated auditory and dynamic visual displays, together with the capacity for kinesthetic learning by building displays through the tracing of figures on the screen.

3. The variety of means of inputting information. Interaction can be through touching the screen display and through pressing keys on the keyset.

4. Immediacy of feedback. Unlike the standard hard-copy workbook sheet, PLATO provides instantaneous feedback on the correctness of the child's activity.

We now feel that we are in an excellent position to make highly sensitive use of these capabilities to extend significantly the problem-solving technology of the classroom.

5.10 SUMMARY AND CONCLUSIONS

In conclusion, despite the difficulties attending an experimental effort which combines exploration of the uses of a new and developing technology with extensive real-world implementation of that technology, PERC has experienced considerable success in gaining user acceptance. Acceptance has increased with the degree of user control of the system; this statement applies to both teachers and students. Teachers and students will also enthusiastically interact with materials developed by others; the degree of use depends upon the validity of the lesson design, for which PERC has developed effective guidelines.

At the same time, PERC has encountered three major barriers to productivity in terms of courseware development. First, the inappropriateness of the automated routing system to the classroom situation. Second, the large number of classrooms involved in the implementation, resulting in a state of affairs requiring a relatively sizeable commitment to supervisory and liaison staff. Third, the initial definition of the scope of the project: to produce a complete kindergarten through first grade curriculum rather than to focus on those aspects of reading which teachers feel they need help in addressing and which PLATO technology can uniquely impact. This commitment resulted in the production of a relatively large number of lessons (especially phonics) which attempt to impact auditory skills which are probably better addressed off-line in situations which allow the child to see the human face. As a consequence, such valuable integrating and motivating activities as games and sentence and story building were neglected.

A fourth obstacle to development was the necessity of dealing with the random-access audio device, the first generation of which was still under development as the project was initiated. Unreliability in production of sound and the cumbersome, unreliable, and time-consuming process of disc duplication complicated lesson analysis, delayed lesson development, consumed unreasonable amounts of staff time, and held up delivery of lesson materials to classrooms.

The lastest generation of audio devices, however, represents a considerable improvement over earlier devices, in both reliability and ease of student use. Audio capability, and preferably random access capability, are indispensible to an early reading program if the child is to work independently at a terminal. (See Appendix 5.3.) When the audio is working properly, it provides a vital communications link, especially to the non-reading or language-impaired child. Therefore, despite the problems and frustrations attending the development of a complex electro-mechanical system such as the audio device, it is apparent that audio capability is an important adjunct to the PLATO system. Ways of improving reliability and streamlining disc production should be explored; alternatives to the present concept of audio delivery should be investigated.

To elaborate on the latter point, even when it is working optimally, the present system does require that discs be produced and physically delivered to the classroom. Changes in lessons involving altered messages require that new discs be produced and delivered. Without the new discs, the revised lessons can not be implemented in the classroom. Some method of delivering electronic programmable audio, which can be altered by the lesson designer and instantly be made available to all sites, would vastly expedite lesson design and revision. However, until such devices as the Votrax deliver more natural speech sounds, the present model of recording natural human speech and delivering it with a random access device is preferable.

As a consequence of the lessons learned over the course of the project, members of the PERC staff have in the last months of the NSF-supported effort made massive changes to the lesson delivery system, as well as improvements in the lessons themselves. The result has been to extend teacher control over PLATO resources and to shift focus from the concept of PERC as an automated curriculum running in parallel to other classroom activities to the concept of PERC as a powerful resource to be used for specific purposes at the discretion of the teacher.

Our experience with these modifications leads us to believe that we are now in an excellent position to accomplish the following goals:

1. To implement lesson and service routines at remote sites.

2. To test the effectiveness of alternate lesson sequences.

3. To design and implement a large library of materials taking advantage of the unique capabilities of PLATO.

4. To design a teacher training package which would bring teachers to competence in managing PLATO resources in two to four hours of instruction.

In the year following termination of the NSF contract, PERC staff members are continuing to work toward these goals.

5.11 PERSONNEL

Below is a list of major staff involved in the PERC Project from 1971-76.

John Risken	Director	June 1971 - February 1976
Bob Yeager	Senior Author	August 1971 - present
Priscilla Obertino	Director	February 1976 - present
	Site Supervisor	August 1971 - February 1976
Lezlie Fillman	Graphic Designer	June 1971 - August 1975
	Site Supervisor	August 1975 - present
Dorothy Silver	Site Supervisor	June 1974 - present
Carl Webber	Programmer	September 1972 - October 1975
Kathy Lutz	Lesson Designer	September 1972 - August 1973
Ruth Becker	Site Supervisor	June 1974 - August 1975
Janet Busboom	Reading Consult.	July 1971 - December 1971

Many others, including student hourlies and other part-time employees, have made substantial contributions to the Project.

6. COMMUNITY COLLEGE PROGRAM

6.1 DISCUSSION AND SUMMARY OF THE COMMUNITY COLLEGE PROGRAM

This final report summarizes the activities of the "Community College Project," a programmatic effort organized within the Computer-based Education Research Laboratory (CERL) to introduce the PLATO system into widespread use in a number of community colleges within the state of Illinois. The report focuses especially on an organized field test and demonstration of the system which was carried out between September, 1974, and May, 1976, in accordance with a contract #C-723 between the National Science Foundation and the University of Illinois.

The Community College field test and demonstration program called for collaboration and cooperation between a closely knit group of professionals at the University of Illinois (hereafter called the CC Project staff, the coordinating staff or the project coordinating staff) and a very large and diverse family of "users," consisting of faculty members, administrators, professional support personnel, and students in a number of community colleges in the state of Illinois. The role of the CC project staff was multifaceted, and changed during the life of the program. During the years preceding the field test, it focused on the development and coordination of instructional materials, during the latter course of the program, the project staff acted in an entrepreneurial and facilitating role - to introduce new instructors to the use of this new medium, and to overcome a variety of barriers, from serious delays in the installation or maintenance of terminals to occasional misunderstandings about the nature of the system or project goals.

Throughout the entire period (from January, 1972 to the present) the success of the Community College program depended on the deep insights and generous good will of the community college staffs, headed by Dr. Oscar Shabat, Chancellor, and Dr. Hymen Chausow, Vice Chancellor for Faculty and Instruction, of the City Colleges of Chicago and Dr. William Staerkel, President of Parkland College. It also depended on the tolerance, commitment, and motivation of a large "group" of community college faculty members, far too numerous to acknowledge by name, who made the individual and collective decisions as to whether and how PLATO would be used.

The basic organization of the CC project and field test was according to subject area. This fact is of interest in itself; it is based on the way in which the users related to each other. The critical decisions were made at the grass roots level where faculty members identify themselves as English teachers, mathematics teachers, etc. In addition, the various instructor-users of PLATO tended to learn from and cooperate with instructors in the same discipline at other institutions in putting together a viable curriculum. Thus, the body of this report is organized according to the five subject areas: Accountancy, Biology, Chemistry, English, and Mathematics. For each subject area, we present a summary account of the development of lesson materials, the implementation and usage of PLATO in the classroom, and the response of students and faculty to PLATO instruction. A description of lesson design, implementation, and use is presented in the text; more detailed information on lessons, authors, usage data, equipment availability and function, and personnel and administration have been assembled as appendicies that are appropriately cross-referenced in the text. In general, this report attempts to present the history of the project and the field test in terms of the problems faced in the course of implementing the field test and the responses or approaches to working out solutions.

6.1.1 Basic assumptions and goals

From its inception, the project was intended both to enhance and to assess the adoption of PLATO by the community colleges under normal administrative conditions, i.e., without imposing external incentives or contractual commitments on the faculty or staff. Consequently, choices of curriculum, sites, and methods of implementation were selected, adapted or modified under the complex and demanding conditions imposed by normal community college operations. In particular, the individual instructors had virtually complete power to decide whether and how to utilize the system.

Although the original planning emphasized General Education Development (GED) materials and the sciences, other areas were later incorporated into the program: these were Accountancy, English, and Mathematics. Several other subject areas, not fully under the coordinating purview of the Community College Project, were also introduced and documented, including instruction in nursing skills, music, language, auto mechanics, physics, and computer sciences. Site selection, that is, the selection of the community colleges at which PLATO terminals were to be installed was made with a view to diversity in the make-up and character of the students and faculty. Participation in the field test and demonstration was on a completely voluntary basis for individual faculty and students; no contractual or monetary incentives were imposed.

During the course of the project, the coordinating staff gave special attention to the evaluation or measurement of key factors relating to acceptance of the new medium. These included (1) characteristics of effective lesson development in the PLATO medium, (2) adequacy of lesson content, and (3) appropriateness of lesson level. Additionally, the project staff tried to identify what factors, beyond the characteristics of instructional materials, are associated with the acceptance or rejection of PLATO in the classroom. The following parameters were sampled or surveyed: (a) instructor and student attitudes; (b) the nature and extent of usage of lessons and (c) implementation procedures.

In the final phases of the project, the project staff worked to develop methods for the local (community college) planning and control for continuing use of the PLATO system after the completion of the field test and demonstration.

6.1.2 Make-up of the Community Colleges

The field test of the PLATO system was carried out at four community colleges and a vocational school, which differed significantly in educational mission, administrative style, faculty make-up and student population profiles. The five institutions, all of which are continuing the utilization of PLATO following the field test, are Kennedy-King, Malcolm X, Wright, the Chicago Skills Center (all divisions of the City Colleges of Chicago), and Parkland College at Champaign, Illinois. In this report each institution is identified by number to avoid direct connection of data to individual instructors and students. At the outset, each college agreed to take part in the field test and demonstration by providing (1) space and environmental control for a "class-room" of terminals, (2) a portion of the cost of communications between CERL and the community college site, and (3) insurance for installed equipment. In addition, each college provided released time to a limited number of instructors for curriculum development in selected subject areas.

Two of the four colleges, Parkland and Wright, offer a substantially traditional program leading to further study for the Baccalaureate degree; although both offer two-year career programs and continuing education, a substantial proportion of their students typically go on to continue their education at a four-year institution. The student population at both of these colleges is largely white and of middle income. Located in Chicago, Wright serves an almost exclusively city student body, while Parkland serves a mixed urban and rural student population. Malcolm X and Kennedy-King also offer a mixture of traditional, career, and adult education programs; their student populations are made up largely of urban minorities. Kennedy-King College specializes in health and medical science professions. All four community colleges divide the academic year into two semester terms, although one school (Parkland) converted from a trimester system to two semesters during the field test. All four offer traditional lecture and laboratory instruction.

The fifth school, the Chicago Skills Center, provides instruction in general education and practical vocational subjects intended to develop fundamental skills to qualify students for employment in specified trades or vocations. Students at this school are paid to attend classes; courses are scheduled cyclically as needed, rather than regularly by semester terms; students continue in a given course until the training is completed and they are placed in a job. The school aims to train students to become productive workers; many of the students have not previously held permanent employment.

None of the schools are residence institutions; they serve populations that are mobile; some maintain strong ties with their local communities and environments. The major portion of the students are self-supporting, work regularly scheduled hours, and spend little time on campus. In fact, even for students who are not employed there is a lack of participation in out-of-class activities. For example, many students are females with dependent children; they are also limited in their time away from home.

All five schools emphasize teaching rather than research and stress cost-effectiveness in teaching and administrative methods. At four of the five institutions the faculty is organized for collective bargaining purposes, and many faculty members are especially conscious of the possible effects of computer-assisted instruction in displacing or changing the role of the classroom teacher.

Table 6.1.1 presents the distribution of terminals and associated peripheral equipment in the colleges for the field test.

Each cooperating community college appointed a member of its faculty to be a PLATO site coordinator during the field test. These individuals scheduled the use of terminals, trained teachers in course management, maintained records of use and equipment, and programmed instructional materials. In most cases, they were assisted by part-time student help. These people reported directly to their local administration and interfaced with the University of Illinois staff in a cooperative and consultative manner. They were expected to provide at the local level the necessary technical support to carry out the community college responsibilities for the project. In addition, each college released selected teachers to contribute to the development of instructional materials for one or more subject areas. This program broadened the familiarity of faculty members with the project but the percentage of released time and the limited duration of exposure by a "released" instructor (often only one semester) sometimes detracted from the development of a highly organized curriculum project.

TABLE 6.1.1

Equipment in the Community Colleges - Spring, 1976

School	Terminals	Slide Selectors	Touch	Audic
Dawson	16	16	16	0
Kennedy King	24	24	24	0
Malcolm	24	23	24	0
Wright	24	24	24	0
Parkland	30	30	30	0

The coordination of PLATO activities at the community colleges was carried out under the direction of Dr. Chris Dimas for the City Colleges of Chicago, and Mr. Donald Swank, Dean of Instruction and Mr. David L. Johnson, Director of the Learning Resources Center for Parkland College.

6.1.3 Project Coordinating Staff (CERL)

During the initial phase of the Community College Program, from January, 1972 to July, 1973, the coordinating staff was directed by Dr. Alan Knox of the College of Education and Dr. Richard Videbeck, project coordinator. This phase of the program was very limited in funding; it was largely aimed at instructional development. A major fraction of the limited support went into the training of a new group of authors, an enterprise that was quite new both to the project coordinators and to the CERL laboratory as a whole. (Up to this time, most authors had been self-selected faculty members on the University staff, oriented to writing lessons for use in their own classes.)

In July of 1973 additional funds were made available for the CC project. Dr. Daniel Alpert, Associate Director of CERL assumed responsibility for the project and enlarged and reorganized the project coordinating staff. Five area coordinators were appointed to handle curricular development, implementation, and liaison: Accounting, Dorothy Pondy; Biology, Mary Manteuffel and Kathy Herrick; Chemistry, Dr. James Ghesquiere and Robert Hubel; English, Dr. Pauline Jordan; Mathematics, Dr. Louis V. DiBello. Dr. James Ghesquiere and Dr. Elaine Avner coordinated the activities of this group during the first year and Dr. Pauline Jordan assumed this responsibility during the field test from 1974-1976.

The staffing assigned to the various subject matter groups was geared to the volume of completed courseware that was available for use in July, 1973.

In accounting and chemistry, many lessons had been authored by University of Illinois faculty; therefore, relatively small staffs were needed. The biology group was assigned a full-time programmer to assist community college faculty in lesson development. The mathematics group averaged four full-time professional employees and the English group three professionals in lesson design and programming. There was appreciable turnover in staff; although the total full-time equivalents corresponded to about 10 or 12 professionals, a total of 30 individuals worked for the project between July, 1973 and November, 1976. In many cases, positions were held by graduate students without previous experience in curricular design or computer-based education. Thus the training period sometimes exceeded the time devoted to the active production of useable courseware. Frequently staff members moved on to more permanent positions because of professional opportunities or personal preference. The extent of staff turnover and the level of professional experience should be viewed as significant factors affecting the project.

6.1.4 Liaison

In general, the relationship between the cooperating colleges and the CERL staff was characterized by a strong level of rapport and collaboration. In addition to frequent communications via PLATO notes files and individual visits to the colleges, the staff arranged bi-weekly subject area meetings to review lessons, design courseware, and plan implementation.

To provide familiarity with the use of the system, senior members of the project staff offered two University of Illinois extension courses, "Introduction to Computer-based Education" and "Preparation of Computer-based Instructional Materials" for City College faculty members in Chiago.

It is interesting to note that a number of teachers who took the courses were from campuses not participating in the field test; these faculty members were strong proponents for the expansion of the PLATO system to other campuses of the City Colleges. Dr. James Ghesquiere taught the introductory course in Spring, 1974, Dr. Pauline Jordan during the fall of 1974 and 1975, and the spring of 1976, and Dr. James Kraatz in spring, 1976. A total of 85 faculty and staff members were enrolled as students.

Two extensive workshops were held during the summer of 1975 involving the CERL coordinating staff and Community College site coordinators. These workshops served to provide planning support between the two field test years; in particular, specifications were drawn up for user questionnaires and data collection. The results of the workshops are published as The Community College Users Report, Fall, 1975.[1] (Appendix S6.1.1)[2]

A detailed review of the various liaison activities is provided in the subject area summary reports below.

6.1.5 Courseware

A measure of the accomplishment in the area of courseware development is the publication of subject area catalogs of courseware which not only provide useful indexes of the extensive courseware available, but represent a significant contribution in their own right. (Appendices S6.1.2 through S6.1.6 They include PLATO lessons by authors within the project and by others who made their materials available for use in community colleges. These documents provide rather detailed descriptive information about all such courseware. To give an impression of the magnitude of this enterprise, we list below a numerical summary of the entries in each catalog:

[1]Alpert, Daniel and Pauline Jordan, The Community College User's Report, Fall, 1975; CERL, University of Illinois, Urbana, Illinois 61801, 1976.

[2]Appendices prefixed "S" indicate they are supplemental separately bound volumes rather than textually inclusive in this document.

Accounting	48
Biology	84
Chemistry	36
English	117
Mathematics	124

The catalogs also demonstrate the non-directive thrust of curricular development for the Community College project. The implementation strategy from the outset encouraged and was dependent on community college teacher participation in the preparation of materials. One of the best means for enlarging the understanding of this new technology was to involve instructors in the authoring and review process. Encouraging teachers to design and program lessons resulted in an eclectic rather than a sequential process for curriculum evolution. In some cases, more than one lesson was written for the same topic, and the use of lessons showed varying individual teacher preference in the selection of topics and instructional design. As might be expected from this approach, the available lessons also utilize differing formats or teaching strategies, e.g., drill and practice, tutorial instruction, gaming, testing, simulating experimental apparatus, information storage and retrieval, and record keeping. In general, teachers controlled the style and extent of the use of PLATO in the classroom; they typically viewed PLATO as an adjunct to classroom instruction and personally selected lessons from the catalog that were well coordinated with their syllabi and teaching styles. In many cases, the lessons written by Community-College instructors represent the author's first efforts and should be considered prototype instructional materials. In some cases, the process of developing familiarity with PLATO through authoring the lesson was much more important than the product; also, this experience enabled the instructors to better select from available lessons those appropriate for use in their own programs.

6.1.6 Usage

The following is a summary of the extent of usage over the two year period:

Date	Total # Students	Total # Hrs of Instruction
Sept. 1974 - June 1975	8236	34,632
Summer 1975	1488	7,040
Fall 1975	5606	25,221
Spring 1976	6350	30,747
Total	21,680	97,640

A breakdown by school and subject area for each period appears in Tables 6.1.2 through 6.1.5. Each subject area report discusses usage in greater detail and may be consulted for more specific analysis.

6.1.7 Data Collection

The PLATO system level data program provides a collection of virtually every keypress of every student. Moreover, the course records give individual and average number of students and hours of use. Therefore, the problem was one of adequate selection and interpretation of data. Working closely with the PLATO Evaluation and Educational Research group (PEER) and in conjunction with the external evaluation, Educational Testing Service, the Community College project staff developed several programs to yield information on time, interactiveness, fit and misfit of instructional programs. This work was done primarily by Tamar Abeliovich Weaver and Stephen Boggs. Problems in design, collection, and especially interpretation of student performance data is more appropriately discussed in the subject area reports relevant to the target audience, specific lesson, and circumstances of usage.

TABLE 6.1.2. USAGE BY USAGE BY INDIVIDUAL STUDENTS OF COMMUNITY COLLEGE PLATO LESSONS

JANUARY 1976 - MAY 1976

College	Accountancy		Biology		Chemistry		English		Mathematics		Other	
	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs
#1	97	381	----	----	161	1099	219	890	204	909	195	1124
#2	32	230	----	----	----	----	313	1200	225	1472	----	----
GED							80	235				
#3	77	349	436	2601	171	996	425	2288	182	1309	116	251
GED							130	401	157	780		
#4	20	101	314	1230	460	2989	349	991	217	511	51	101
#5	268	1208	424	2637	184	1310	179	617	161	676	503	2031
TOTAL	494	2269	1174	6468	976	6394	1695	6622	1146	5657	865	3507

Total # Students: 6350

Total # Hours: 30,747

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TABLE 6.1.3

AGE BY INDIVIDUAL STUDENTS OF COMMUNITY COLLEGE PLATO LESSONS

September 1974 - June 1975

	#Stu	#Hrs
Accountancy	1197	5478.36
Biology	1506	8804.68
Chemistry	1308	6439.24
English	2633	8020.86
Mathematics	1592	5989.21
TOTAL	8236	34632.35

TABLE 6.1.4

COMMUNITY COLLEGE PLATO USAGE BY INDIVIDUAL STUDENTS

Summer 1975

College	Accountancy		Biology		Chemistry	English		Mathematics		Total	
	#St	#Hrs	#St	#Hrs		#St	#Hrs	#St	#Hrs	#St	#Hrs
#1								59	398.80	59	398.80
#2	25	200.40				222	1736.00	203	1545.80	450	3482.20
#3			65	159.08		178	564.10	114	244.00	357	967.18
#4			83	192.09		158	723.90	55	120.90*	296	1036.89
#5	143	606.19	62	153.14		63	295.00	58	100.60	326	1154.93
Total	168	806.59	210	504.31		621	3319.00	489	2410.10	1488	7040.00

*An additional 67.6 hours of usage occurred under a multiple sign-on.

TABLE [illegible].1.5

USAGE BY INDIVIDUAL STUDENTS OF COMMUNITY COLLEGE PLATO LESSONS

September - December 1975

College	Accountancy		Biology		Chemistry		English		Mathematics		Other[1]	
	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs
#1	182	1073	----	----	78	804	257	1043	150	378	230	777
#2	10	49	----	----	----	----	154	493	66	255	----	----
#3	35	298	413	2247	146	845	555	2097	342	1316	173	394
#4	35	411	188	631	246	1700	399	1184	107	367	103	372
#5	335	1237	471	2681	197	1479	181	1034	40	240	513	1816
TOTAL	597	3068	[illegible]	5559	667	4828	1546	5851	705	2556	1019	3359

Total # Students: 5,606

Total # Hours: 25,221

[1] Itemized on next page.

6.1.8 Some Observations and Conclusions

1. If one takes into account the central fact that involvement in the utilization of PLATO was carried out on a voluntary basis by faculty members and students, the sheer magnitude of the field test utilization of the PLATO system in the Community Colleges is ample testimony for the receptive attitude and substantial acceptance of the system. Consider the following summary data:

Total number of instructors using PLATO in their instructional activities (approximate): 175

Total number of students: 21,680

Total number of lessons available to (and used by) CC instructors: 379

Total number of hours of instruction: 97,640

These data speak for themselves; there was a widespread belief in the value and efficacy of computer-based education on the part of administrators, faculty, and students. In our view the field test showed that there is a fertile environment for widespread adoption of the system in community colleges if and when the economics of the system makes it possible.

2. Economic considerations. In the community colleges that took part in the field test, there is a significant and well-motivated commitment for continuing the use of the PLATO system for supplementary instructional purposes. However, it is also clear that the current costs of access are too

high to anticipate a short-term widespread use of the system in providing standard instruction in community colleges. Despite the widespread enthusiasm for doing so, it is questionable whether the community colleges could afford to continue the access to the CERL PLATO system without some subsidy for the next few years. Thus the future widespread application of the system in Community Colleges calls for the development of new versions of the system (PLATO V, etc.) that would permit substantially reduced costs.

In the near term, however, the continued utilization of the system can be justified in terms of research and development in using the new medium, for conventional instructional missions. Alternatively, we can explore applications in which the benefits would justify higher costs. In general, such applications would entail either a set of activities not now being accomplished by the community colleges, a new and different (additional) student clientele, or a significant change in the character of the educational uses of the system. Such possible applications are referred to in 4 below.

3. The community college project called for improvisation and invention in administration; the establishment of an administrative process for encouraging the adoption of a new technology had no precedent in the experience of either CERL or the community colleges. Furthermore, the original NSF contract, which if anything, overspecified the details of the field test in terms of courses, numbers of students and faculty, schedules, etc., provided neither sufficient funds nor a format for implementing a complex program of curriculum development, faculty instruction in the use of the system, and the development of effective liaison procedures. In addition, the available project staff was for the most part inexperienced in teaching or in the use of PLATO or both.

These considerations all led to a significant amount of trial and error in the implementation process. In retrospect, we consider it a rather remarkable achievement to have carried out the many-faceted field test that is described herein. It goes without saying that with the benefit of hindsight we would have done a number of things differently.

For example, we would upgrade the personnel specification for some jobs and lower them for others. We would have focussed some curricular development effort in other directions, etc.

4. Perhaps the most significant observation we wish to make is related to the fact that the goals for the entire project were prescribed at a highly specific level prior to the initiation of the program. The prescription of goals for the field test cannot be said to have been identical with the goals of CERL; rather they were based on the commitment by the sponsoring agency to an independent prescriptive evaluation by an external contractor.

In particular, CERL was committed to the widespread dissemination of PLATO utilization under normal administrative conditions. Thus the project was confronted with two somewhat orthogonal purposes: carry out a structured field test in specified subject areas, and at the same time, build a missionary spirit of exploration and experimentation by dedicated faculty leadership, wherever it could be identified. These different objectives did not make it easy to carry out a responsive process for curriculum development and evaluation.

From our point of view the prescriptive approach to the field test and evaluation had both positive and negative consequences. On the positive side, our project staff was called upon to fulfill a contractual commitment to a widespread use in a very short time-scale. This elicited many innovations in liaison, in faculty development, and in cooperation between staff members at community colleges and those at a comprehensive university. This collaboration in itself is one of the major achievements of the program and one that deserves further discussion and articulation.

On the negative side, the prescription of goals in specific subject matter applications probably forced the trials into some applications that did not optimize the use of PLATO either in terms of economics or effectiveness. Furthermore, this approach prevented (by sheer limitation of resources) the exploration of applications of the system into areas which are not already being satisfactorily handled by the community colleges. For example, there is a significant interest in the possible use of PLATO in such applications as academic counseling, special tutoring, administrative procedures (record keeping, testing, business procedures, etc.), and on-the-job staff training. These applications might well be justified under conditions of higher costs than would be acceptable for standard instruction. In other words the prescriptive terms of the contract forced the major effort into applications that were perceived as timely in 1970 but not necessarily so in 1976.

In dealing with an inherently new technology, we would recommend in the future that ample flexibility be built into the program to permit

°administrative flexibility and the possibility of adaptation to meet unforeseen conditions

°flexibility in the specification of goals

°self-evaluation of the project (possibly with an external audit to insure objectivity) as opposed to the external evaluation imposed on the present program.

6.2 ACCOUNTANCY

6.2.1 Introduction

Accountancy was intended to be a part of the PLATO demonstration project from its inception. Professor Thomas Lenehen of the business faculty of Wright College, City Colleges of Chicago, was a member of the *ad hoc* group of faculty and administrators from the University of Illinois and the City Colleges of Chicago, which planned the early stages of the demonstration project and helped to prepare the initial curriculum. Because of Lenehen's early association with the project, the accountancy curriculum was almost fully established and in operation prior to the formation of the Community College Project staff at CERL and prior to the beginning of the field test in September 1974. Professor Lenehen's association with the project is discussed more fully in Sections 6.2.2 and 6.2.3 below.

In July 1974, a half-time coordinator was added to the community college project staff to assist faculty in using the accountancy lessons. Because the curriculum was established early in the program, the coordinator's duties consisted principally of encouraging and facilitating the use of existing materials, performing liaison between the lessons' authors and the using faculty, collecting and maintaining records of lesson use, and reporting on the program.

Since May 1976, the accountancy section of the Community College Project has operated without the services of a coordinator. However, because curriculum and a pattern of use in the community colleges are now well-established and because community college faculty have assumed the responsibilities, management, and implementation, for curriculum development, the absence of a coordinator should not be severely felt.

6.2.2 Lesson Development

The PLATO accountancy curriculum presently consists of fifty lessons, of which forty-eight are currently in use and two are being readied for service. Of those fifty, forty-seven were written by two persons, either individually or jointly. Professor Thomas Lenehen of Wright College and Professor James McKeown of the University of Illinois at Urbana-Champaign prepared all but the lesson "Partnership" currently in use in the accountancy curriculum.

Much of this work was done at the University of Illinois in 1972-73, when Professor Lenehen was assigned to the University of Illinois for year-long training in PLATO. During that period he co-authored and programmed eleven lessons for PLATO III which were subsequently adapted to PLATO IV.

Professor McKeown collaborated with Lenehen on those eleven lessons and subsequently authored thirty-six more lessons, individually or with the assistance of other faculty and graduate students. These forty-seven lessons are all applicable, in varying degrees, to the community college curriculum. Since the lessons were intended to serve not only the community college, but also the accountancy curriculum of the University of Illinois, some lessons, espcially those on cost accounting and management analysis, have less application to community colleges. Nonetheless, the available PLATO lessons form a fairly comprehensive coverage of material typically included in introductory accounting courses. Specific applicability will depend upon the scope and focus of any individual course. (See Accountancy Appendices

6.2.1 and 6.2.2). The close working relationship of the authors has resulted in lessons of similar format and uniformity of approach.

Three additional lessons have been prepared by other community college faculty. Professor George Trent of Wright College wrote the lesson "Partnership." Professors Eugene Costabile and Robert Weaver have each written one lesson which are now being readied for classroom testing. Costabile's lesson "Dependent Exemptions" and Weaver's "Payroll and Payroll Taxes" should be ready for use in the 1976-77 school year. An index of accountancy lessons is included in appendix S6.1.2 of the report.

6.2.3 Lesson Design

The greatest portion of the lessons, those by McKeown and Lenehen, were designed to provide self-contained instruction which could be used to replace either classroom work or homework. Typically, the lesson provides a short introduction to the topic and step-by-step analysis of a sample problem. The student is then asked to solve one or more similar problems using the same method. Review of the sample is provided, as an optional aid, to be selected by the student if he needs assistance. The lesson is programmed to anticipate certain incorrect responses and to provide the appropriate feedbace for each wrong answer. Although lessons are self-contained, only McKeown and Lenehen have consistently used them to replace instruction wholly.

6.2.4 Implementation

6.2.4.1 History

Upon return to School #5 Fall 1973, Instructor G. assumed responsibility for coordinating all PLATO activities. During that time he was able to recruit additional accounting instructors for the PLATO program. During the initial phase of the field test in Fall 1974, use of PLATO in some form or another in accounting and business math courses was so extensive that Educational Testing Service (ETS) had difficulty in securing non-PLATO control groups for their evaluation of the medium, especially among instructors teaching day-time classes. Use at one school decreased in Fall 1975 because of the loss of two faculty members, decreasing the number of accounting sections which could be offered.

Although School #5 provided the greatest use of PLATO, the lessons were used at other colleges. At School #4 only two instructors offered introductory accounting, one of whose classes served as control groups during Fall 1974. In Spring 1974, PLATO was made available optionally to all students who wished to use the medium voluntarily. In Fall 1975 one instructor used PLATO, and one of his two sections was reserved as a control group. In Spring 1976, the same instructor became co-chairman of the Business Department and was simultaneously granted released time for PLATO lesson development, both of which precluded use of PLATO in class. PLATO was made available for his own second semester accounting students, who spent an average of five hours each using lessons.

At one college PLATO was not as fully implemented. The sole interested instructor was not a specialist in accounting and was a junior member of the staff. Consequently, he was assigned few courses in accounting. A tentative program established in Fall 1975 to provide one PLATO section and one control group was not fully realized because the instructor's low seniority gave him little choice of teaching assignments and there was some administrative reservation in accomodating the scheduling requirement of the test program. He was, however, able to schedule occasional use of PLATO in some courses.

At School #2 two accounting instructors used PLATO. Because of School #2's purpose and program, classes in the Accounting Clerk courses are limited to sixteen students each. One class was set aside for students for whom English is a second language. In these classes, which ran full days until course completion, instructors tended to supplement PLATO instruction with classroom materials.

6.2.4.2 Usage

The ways in which PLATO was used varied from shcool to school and instructor to instructor. Some faculty used PLATO only as an outside-of-class supplement; others used PLATO as a class substitute one day each week or every other week; still others used PLATO only for remedial instruction; only one used PLATO regularly as an integral part of classroom instruction. (See Accountancy Appendix 6.2.3).

Of particular interest is the use made at School #1. There, PLATO accounting lessons were used in the Learning Lab. Sequences of lessons, individually designed for each student, were made available for all accountancy students who sought them, either to remedy individual deficiencies or to provide extra practice. The generally greater accessibility of terminals at School #1 made this Learning Lab arrangement particularly effective. The system was devised after an unsuccessful attempt by one instructor to use

PLATO in the classroom in Fall 1974, when shortage of class time, available computer memory, and mechanical problems frustrated use. The instructor continued to use PLATO and to actively recruit other faculty to PLATO after the system of optional use was devised.

Student use data is summarized in Accountancy Appendix 6.2.4. In brief, lightest use mas made of PLATO in the summer terms of 1974 and 1975, principally because of lower enrollments. Small total hour usage and smaller numbers of student users in Spring 1975 and Spring 1976 are attributable to 1) smaller enrollments in Accounting 102, and 2) lack of lesson applicability of PLATO accounting lessons to the Accounting 102 syllabi. During the two years of the field test 2,591 students used PLATO for a total of 12,054 hours of accountancy instruction.

6.2.4.3 Instructor Attitudes

Of the seven instructors whose judgment on the value of PLATO lessons are recorded in the Users' Report, March 1976, four thought the lessons of high quality, and three of average quality; all seven found the learning level of the lessons appropriate; five of seven thought the number of lessons sufficient, one found them more than sufficient, and one less than sufficient.

Of nine accountancy faculty members polled in Fall 1975, four stated they would use their own time to improve PLATO instruction, four said they would not, and one did not respond. Of those who said they would not, only one had taken a University of Illinois extension course in PLATO and had designed one or more PLATO lessons. The three others had neither taken an extension course nor designed a lesson. In contrast, of the four who responsed that they would devote their own time to improvement of PLATO, two had taken an extension course and designed at least one lesson; two had done neither. There seems to be a correlation between enthusiasm for PLATO and experience and training in using it. The greater the familiarity and formal instruction, the greater the enthusiasm for its continued improvement.

6.3 COMMUNITY COLLEGE BIOLOGY

6.3.1 Introduction

The field test of PLATO in community college biology has clearly demonstrated one characteristic of life -- GROWTH! Since Fall 1974 overall usage has more than doubled as measured by total students (540 - 1174) and total hours logged on the system by these students (2484 - 6468). The number of instructors who participated each semester has tripled (8 - 24). Usage by Individual Students of Community College Biology Lessons for each period of the field test appears below (Table 6.3.1).

Table 6.3.1

USAGE BY INDIVIDUAL STUDENTS OF COMMUNITY COLLEGE BIOLOGY LESSONS

	Fall 1974		Spring 1975		Fall 1975		Spring 1976		Totals by Schoo	
	# Stu	# Hrs	# Stu	# Hrs	# Stu	# Hrs	# Stu	# Hrs	# Stu	# Hrs
School #3	357	1,826	359	2,117	414	2,239	436	2,601	1,566	8,783
School #4	102	462	262	1,282	204	636	314	1,230	882	3,610
School #5	81	196	375	2,922	479	2,679	424	2,637	1,359	8,434
TOTAL	540	2,484	996	6,321	1,097	5,554	1,174	6,468	3,807	20,827

A total of 29 instructors were involved for one or more semesters during the two year field test (25 for at least three semesters), teaching a total of 75 PLATO classes. (See Biology Appendix 6.3.1: Biology User Participation.)

With this growing group of experienced users, the need for a forum to discuss problems became apparent. Therefore, after the first semester, regular meetings of biology users were initiated. The most common problem identified in these meetings was the need for more lessons which were suitable for the City Colleges of Chicago (CCC), both in content and depth. Intense curriculum development activities began in earnest during Spring 1975. As a result of these efforts, ten new lessons were written and eight lessons were revised. Biology Appendix 6.3.2 details the sources of lesson development.

These figures demonstrate the fulfillment of two major objectives of the biology project: (1) the establishment of a stable group of instructor-users committed to the use of PLATO in their courses and (2) the beginning of a regular program of revision and development of PLATO courseware by the colleges themselves.

6.3.2 Lesson Development

At the start of the field test in Fall 1974, the PLATO biology curriculum was compiled from those lessons already on the system which were developed under a variety of auspices at the University of Illinois and the City Colleges of Chicago (CCC). At the outset there were 44 lessons representing about three years of independent lesson development by five contributing agencies: (1) University of Illinois at Urbana-Champaign (UIUC) extension courses conducted at CCC; (2) UIUC Biology 101-102; (3) UIUC Botany 100; (4) UIUC NSF project, and (5) University of Illinois at Chicago Circle Biology 101-102. The curriculum grew from 44 to 84 lessons during the two years of the field test. Biology Appendix 6.3.3 lists the biology lessons available during the two years of use. A total of 23 of 84 lessons (27%) currently available were written or revised with regard to the needs of the City Colleges.

For the duration of the project, PLATO was used in four introductory biology course sequences (Biology 101-102, 111-112, 126-127, and Botany 201-202) at the City Colleges of Chicago. However, of the four sequences, lessons were only explicitly developed by the CCC for General Biology (101-102, 111-112). The basic difference between these sequences is a laboratory requirement: 101-102 meets three hours per week for lecture only, 111-112 meets six hours per week, two for lecture and four in two laboratory periods. Anatomy and Physiology (Biology 126-127) and Botany 201-202 are also laboratory courses. The relative amount of available in-class time is important in the discussion of implementation. At present, 52 lessons are relevant to the 101 and 111 curriculum; the remaining 32 lessons pertain to 102 and 112. The Human Anatomy and Physiology sequence and the Botany sequence use lessons chiefly from 101 and 111.

These 84 lessons represent approximately 55 hours of instruction. For recent estimates on the time required for individual lessons see the 1976 Community College Biology Lesson Catalogue (S6.1.3). Data on time were obtained from lesson summary tables (average completion time) and/or from the on-line accounting lesson when available. An accurate indication of the actual length of a lesson is very difficult to determine because time is dependent upon a number of variables. Many of the lessons are open-ended, as in experimental simulations which allow students to alter parameters, many more of the lessons have indices enabling the student to repeat individual sections. In addition, students may come to the session with varying degrees of preparation. All of these factors affect lesson completion times. Since no measure of time will provide an accurate measure of the amount of insturctional material without rigid documentation, perhaps a more realistic use of time data is to concentrate on all actual usage and examine the average total time spent in each lesson.

6.3.3 Lesson Design

The lessons comprising the curriculum were designed by independent groups and were usually intended for limited use by specific student populations. At the start of the field-test many of the lessons had not been extensively student tested and lesson inflexibilities became apparent with wider use. Recognition and discussion of these problems in users' meetings prompted instructors to identify basic design requirements to guarantee that lessons were easy for students to use. These features included: indexing, unlimited use of access keys (e.g., BACK) and HELP available at all questions. All new lessons and lesson revisions by the CCC and community college biology group incorporated these features. The group also established a lesson development procedure which involved periodic reviews during the development process to insure that lessons meet minimum standards before extended student use. Implementing PLATO in Biology Education at Three Community Colleges (S6.3.2) may be consulted for more detailed information.[1] Since criteria for lesson acceptance were initially established in these users' tings, their

[1] M. S. Manteuffel, Implementing PLATO in Biology Education at Three Community Colleges. February 1976, CERL, University of Illinois, Urbana, Ill.

role gradually evolved to that of a review board for lessons generated within the City Colleges.

Another lesson design feature which developed out of these meetings and the field test was the use of drivers (standard lesson coding). Since standard lesson specifications were desired, the use of a driver was a logical development because it allows uniform presentation of critical aspects of the lesson such as the index and quiz. The student, freed from the task of deciphering each author's particular programming conventions, can more efficiently concentrate on the lesson content. Two major drivers were developed and used extensively in a number of lessons: one was written in the community college biology group (S. Boggs) and the other in the CCC programming group (M. Yamada). Most of the revisions which occurred during the field test entailed adapting lessons to these drivers.

In addition to these structural features, four types of instructional strategy are identifiable in various combinations in these lessons. The strategies, practice, tutorial, simulation/model, and inquiry are defined as follows:

<u>Practice</u>. Lessons which assume student has received instruction off-line prior to the session. These lessons are suitable review exercises.

<u>Tutorial</u>. Instructional presentation followed by direct questions on content -- or practice.

<u>Simulation/Model</u>. A real situation is duplicated on-line via PLATO's graphic capabilities. Simulation is used to describe lessons in which each step of a process is controlled by the student; part of this process may include designating parameters and observing the results. Model is used to

describe lessons which involve only manipulation of parameters to alter a graphic display.

Inquiry. Instruction followed by questions and feedback, which guide the student towards a conclusion.

Two additional categories which are represented less frequently are:

Game. Student learns in a competitive setting, playing either against PLATO or a real opponent.

Exam. Test items presented with immediate feedback.

Because many of the lessons were originally intended for small-scale use, there are a group of lessons (by R. Arsenty and G. Hyatt) for which supplemental handouts or workbooks were prepared. Seventeen lessons have supplemental material to accompany them. In Fall 1975, handbooks containing a complete set of handouts were distributed to the colleges and made available in the learning centers. Lessons such as these that cannot stand alone are much more dependent upon conscientious instructor review prior to student use.

Six lessons required the use of the slide selector capability, but the slide selectors were not readied at two of the sites until Spring 1976, and one site is still not 100% operable.

By the last semesters of the project, many of the areas which had been identified as deficient in PLATO lesson material were eliminated. Most instructors felt there was sufficient material for their classes to justify scheduling sessions throughout more than half the semester.

6.3.4 Implementation

The most important variable in PLATO was the acceptance of curriculum. A hard-copy catalogue of lessons was made available in Fall 1974. The catalogue is keyed to an on-line index lesson so the instructor can choose to review a lesson by the catalogue number.

Eleven of the initial 44 lessons were written by CCC instructors; most of these instructors immediately became field test participants. Because the lessons themselves, which were written for an explicit student population, attracted other department members to PLATO. Other indirect generating factors were communication by project personnel, interaction of current users with other faculty, and the curiosity generated by the presence of the terminals. Guidelines for using PLATO were conveyed to instructors in orientation sessions, if the instructors had not participated in the extension course. These sessions included using introductory lesson(s), advice in selecting lessons, reviewing lessons as a student, learning on-line management of rosters and curriculum, scheduling sessions, and student orientation.

In these sessions suggestions for actual usage were made, but instructors were encouraged to develop a mode of usage with which they were comfortable and which was effective in their classes. Most chose to accompany their students for weekly scheduled sessions during classtime. Case study reports from Spring 1975 indicate that twenty of twenty-two teachers scheduled regular sessions. Some teachers experimented with independent (unaccompanied, out-of-class) use. Many instructors indicated they used PLATO during class AND outside of class. In all, complete independent usage was tried by six instructors during the field test. Four were using PLATO in the 126-127 sequence for which few PLATO lessons are appropriate and often used as remediation. Of course, regardless of the number of scheduled sessions, students can use the terminals whenever their schedules permit and terminals are free. Appendix 6.3.4 illustrates in scatter plot format this analysis of optimal versus required usage.

That instructors were reluctant to experiment with independent usage is not accidental. It can be explained in part by the non-resident character of these schools; many students have other activities away from the college campus. Requiring students to use PLATO outside of classtime is difficult because terminals may only be available in a time block that would not accomodate individual schedules. The only time an instructor can be assured of having both students and terminals concurrently available is to schedule sessions during classtime. This imposes special constraints on 101 and 102 instructors, whose classes meet only one-half as often as 111 and 112. Instructors of 101 and 102 courses must require lesson material they feel can completely replace a lecture or they must resort to outside use. Appendix 6.3.5, Statistical Test on Course Usage Data, shows significant difference in mean scheduled sessions, but no significance in mean number of hours spent by students on PLATO between 101-102 and 111-112; hence to spend the same number of hours on PLATO, the 101-102 students must be utilizing time out of class.

Independent usage is appealing in many instances, especially when a lesson is unfinished in a scheduled session. Even when the average time for completion is less than a class period, some students will require extra time. In order for the self-pacing feature of computer-assisted instruction to be utilized effectively, extra time must be available. Lesson indices and

-restart- commands which allow the student to resume a lesson where it has interrupted further enable students to use their time very efficiently.

Based on Spring 1976 course records, the number of lessons made available to students in each course varied from seven to thirty-two. There appears to be no correlation between the number of lessons made available and the number of scheduled sessions. The motives of instructors were clearly different — some expected students to complete all lessons made available, i.e., lessons were assigned; others offered more freedom by providing a wide selection of relevant topics for use as enrichment.

Usage data for individual lessons were accumulated over each of the four semesters. (See Biology Appendix 6.3.6: Lesson Usage, Spring 1976.) Numbers of different students using lessons is presented for all semesters; total time spent by the students on each lesson is also included for Spring 1976. For each of the last two terms the data from General Biology courses is expanded into histograms to illustrate the relative usage of particular lessons across all courses.

Even though all but a few lessons (less than five) have been made available to students by their instructors at one time or another, only 65% (50 of 78) were used regularly, i.e., by greater than ten students or used in both Fall 1975 and Spring 1976. Only 30-40% of the lessons were used by greater than 10% of the students. In Spring 1976, twenty-six lessons accounted for 90% of the total time spent in PLATO instruction. In fact, time in nine lessons alone contributed to 50% of all the usage from this term. Six of these nine lessons were authored by City Colleges instructors and one was written by the Community College Biology Group specifically for use in

CCC classes. However, of the twenty-six lessons that accounted for 90% of the time, fifteen were from outside sources. It appears that the single most important criterion in choosing a lesson is matching the content to course curriculum, not the lesson author or strategy.

6.3.5 Attitudes

Continued participation by instructors reflects the positive reception of PLATO in biology education at the City Colleges of Chicago.

Attitudes toward PLATO have been well-documented in biology via on- and off-line measures. One large scale attitudinal evaluation was conducted with teachers and students in Spring 1975. Results of the questionnaires are detailed in the Community College Usage Report, Spring 1975 (S6.1.1.) and Implementing PLATO in Biology Education in Three Community Colleges (S6.3.1). Briefly, this study determined that the level of teacher experience (prior exposure to PLATO) had an effect on student's attitudes. More positive attitudes were identified among students of "experienced" teachers than in the entire PLATO student population.

This questionnaire revealed that we needed more specific information about student background before each session. The data we had obtained needed to be supported by information on how each lesson was used and how students were prepared. Since our staff was too limited to conduct long-term classroom observations we developed an on-line questionnaire which students encountered when they completed a lesson. (See Biology Appendix 6.3.7: On-line Questionnaire.) The data obtained was often not very discriminating, probably as a result of the limited population which encountered and elected to fill out the questionnaire. The responses which would have been the most revealing, i.e., those students who were unable to finish a lesson or elected not to finish, were the ones we missed.

Throughout the field test an on-line comment lesson was available to students after they completed a lesson. The purpose was to provide students with a forum for their opinions about lessons. During the last year of the field test students were able to choose this as a lesson from their indices thus enabling them to comment at any time. The community college biology staff responded as often as possible to humanize the experience. The comment files were also available to instructors. Very often student comments were the basis for proposed lesson revisions.

6.3.6 Recommendations

The principal goal of the PLATO Community College program has been to optimize the use and acceptance of PLATO in existing institutions. With the establishment of a stable group of users in these two-year institutions, the emphasis should now shift to three areas: curriculum development, curriculum evaluation, and computer management of instruction. Curriculum development was, of course, necessary in the implementation process, and has been pursued from the beginning of the program.

The Biology Users Group elected to concentrate curriculum development on the general biology sequence and this was very effective. Future projects should always concentrate their efforts towards a single goal as well. Some possibilities for curriculum development might include a development of a series of "dry" laboratory activities on PLATO for Biology 101-102 (non-laboratory) courses. This could entail increasing the credit hours for 101-102 (from three to four hours) yet it would not substantially increase the teaching assignment for instructors. If attendance were monitored this could serve as a motivator for independent use. Such a curriculum could build on lessons already in existence, such as "Blood Typing" or "Drosophila Genetics." PLATO can also be used to provide much of the explanation that must accompany actual laboratory exercises. A series of lessons could be developed on laboratory techniques such as "Use of a Microscope." The microfiche capability could be exploited in both these instances, to provide realistic experiences.

Lesson development procedures at the CCC have been satisfactory. Although there has been a tendency to rely on tutorial instruction, the composition of the Review Board helps to maintain a generally dynamic approach to lesson development. Nevertheless, for any group writing lessons, it is advantageous to have a consultant organization for matters concerning lesson design. The community college biology group performed this role for the CCC Biology Review Board during the course of the field test. This function should be continued by some organization, ideally with subject oriented personnel. For subject area development peripheral to biology, such as basic biochemistry, joint meetings with the Chemistry Review Board are recommended.

Curriculum evaluation for educational effectiveness is an area that was impossible to investigate in the real world situation in which the field test was conducted. In order for the on-line response data to be meaningful there must be knowledge of specific circumstances under which a lesson was used; we did not impose any constraints of usage on our instructor-users.

Finally, teachers need to investigate the use of PLATO to manage as well as instruct. Sample curricula should be assembled illustrating various routing options for students and their usefulness in individualizing instruction. Teachers should be encouraged to develop on-line quizzes using quiz driver lessons for their construction. In addition to review and grading for students, these include options for the instructor for analysis of quiz items and for record keeping on student scores.

6.4 COMMUNITY COLLEGE CHEMISTRY

6.4.1 Introduction

The development of chemistry materials for PLATO had been begun by chemists and educators well before NSF Contract C-723 began in January 1972. Consequently, there was no need for creating from the start a comprehensive chemistry curriculum for use in the community colleges. Existing lessons were put in service from the beginning of the demonstration project.

The principal authors of early PLATO materials were Dr. Stanley Smith, James Ghesquiere and Ruth Chabay, of the School of Chemical Sciences; and Robert Grandey and Larry Francis, of the College of Education, at the University of Illinois at Urbana-Champaign. During the course of the project lessons continued to be written by faculty at the City Colleges of Chicago and Parkland, and by faculty and graduate students at the University of Illinois at Urbana-Champaign.

Since lessons were continually under development by interested outside groups, the community college project staff chose to implement lessons rather than develop them. The first chemistry coordinator, responsible for implementation, was Dr. James Ghesquiere, a chemistry author who served as chemistry coordinator from September 1973 to August 1975; the second was Robert Hubel, coordinator from September 1975 to August 1976.

6.4.2 Lesson Development

The catalog of general chemistry material available presently includes 36 lessons and would take the average student approximately 26 hours. In addition, there are 29 organic chemistry lessons averaging 14 hours to complete.

There are one or more lessons in each of the following topics: (See appendix 6.4.1).

Introduction to the PLATO Terminal and Keyset
Math Skills Essential for Chemists
The Metric System
Scientific Notation
The mettler Analytical Balance
Density, Mass, Volume and Specific Gravity
Names and Symbols of the Elements
Properties of the Elements
Atomic Numbers and Atomic Mass
Valence Electrons
The Aufbau Principle and Writing Electronic Configurations
Nomenclature and Formulas
Ionic and Covalent Bonding
Lewis Structures
Historical Development of the Atomic Theory
Determination of Molecular Weight and Percent Composition
Oxidation Numbers
Balancing Chemical Equations
Mass and Mole Conversions
Calculations with Equations
The Gas Laws
Kinetic Molecular Theory of Gases
Ideal Gas Law Derivation Experiment
Molar, Normal, and Percent Concentration of Solutions
Dilution Problems
Freezing Point Depression Experiment
Acids and Bases in Water
Use of a Buret
Titrations and Titration Curves
pH
Chemical Equilibrium
Kinetics
Heats of Chemical Reactions
Inorganic Qualitative Analysis
Nuclear Chemistry

[(See Appendix S.6.1.4 for a comprehensive index of chemistry lessons used in the community colleges.)].

6.4.3 Lesson Design

The city Colleges of Chicago instituted an effective method for the design and production of PLATO courseware for areas in which no lessons existed. A board was formed consisting of any interested chemistry instructors, lesson programmers, a Chicago PLATO coordinator, and the Community College Chemistry Coordinator. The teachers were acutely aware of course materials not addressed by any PLATO lessons. When the topic for a new lesson is identified, one or more of the faculty designs a lesson on paper and distributes it to all members for comments and criticism. Corrections are made to that paper copy to make the terminology of the lesson consistent with the common texts, confusing points are cleared up, and sufficient corrective feedback is incorporated. After review is completed to everyone's liking, the lesson is programmed and reviewed once more. In addition to content errors, the group searches for programming errors. If any major modification must be made, the lesson is reviewed once more after correction. The Chicago City Colleges PLATO Coordinator supervises the procedure, allocating the human and financial resources. In this fashion, lessons useful to all instructors are produced.

This process has worked quite well in chemistry for a number of reasons; 1) many individuals are able to express diverse opinions for consideration by the rest of the board, 2) either by chance, or by the nature of chemists, personalities have blended well, 3) specialists in content, instructional design, and management are present eliminating the necessity for one person to possess all skills.

The type of lesson found most effective was the problem-solving lesson, which presents a typical text-book problem, explains in a step-by-step way similar to the example. A typical format for such a lesson consists of 1) a brief introduction to the topic and presentation of a sample problem, 2) a detailed, explanatory solution to the sample problem, and 3) several similar problems for practice. In the last section, the largest one, several aids are available to the student. A calculator is always available via a student selected option. Other aids include 1) a review of the introduction, 2) answers to the practice problems, 3) feedback to the student, programmed to respond to commonly made errors, and 4) a sequence of remedial questioning which guides the student back toward the correct solution.

The board has produced lessons of this type for topics in molarity, percent composition and dilution, gas laws, formula writing, mole relationships, and calculations involving balanced chemical equations. The board also designed lessons in drill format on nomenclature and oxidation numbers.

Since the PLATO chemistry curriculum also includes a large number of organic chemistry lessons written for use at the University of Illinois, these, too, were made available to the community colleges. Two instructors made use of the organic chemistry lessons. The usage data in the report does not include use of those organic chemistry lessons. If they were included, chemistry usage would increase by four percent (4%).

6.4.4 Implementation

Implementation of the chemistry curriculum in the Illinois community colleges consisted of:

1. Collecting student performance data throughout the whole project and submitting it to Educational Testing Service (ETS) for interpretation and inclusion in their report, as required by contract.
2. Tabulating and reporting total PLATO chemistry usage in the community colleges.
3. Assisting in the design and review of new chemistry lessons written by the chemistry board at the City Colleges of Chicago.

4. Setting up courses for instructors and providing an on-line index of the PLATO chemistry lessons available.
5. Helping instructors with individual problems in the use of the curriculum.
6. Revising the written catalog of general chemistry lessons.
7. Surveying attitudes of teachers who had used PLATO in their classes.
8. Acting as intermediary between chemistry teachers and authors.

Implementation of chemistry materials did not at any time mandate any particular method or methods for the use of the materials. Part of the project was to learn how PLATO would be used if left to the discretion of each teacher. Consequently, no experiments or studies were made which required anyone to use PLATO in an unaccustomed or unwilling manner. Any teacher who used PLATO volunteered to do so. Some chose to conduct both a PLATO and a non-PLATO class in order to create data for analysis by ETS on possible differences between the two methods of instruction. Results of any such analysis should appear in ETS reports, and are beyond the scope of this report.

Usage data does support the observation that instructors used PLATO in different ways including: 1) optional use on student's own time 2) assigned use on student's own time and 3) assigned use during a scheduled class session. When teachers used optional use on student's own time, the lowest usage resulted, students merely browsed through the lessons to satisfy their curiosity about PLATO. Typically, these instructors did not preview any chemistry lessons and consequently made no recommendations to the class. The implication is that greatest use of PLATO resulted when instructors established a PLATO curriculum suitable for their classes. Few instrutors adopted unsupervised use of PLATO. In contrast, a number of instructors committed much time to reviewing available lessons choosing those appropriate for their classes developing new lessons, and encouraging the use of PLATO.

PLATO lessons were also used to replace or reinforce classroom topics. Sometimes PLATO provided practice to achieve mastery; occasionally a topic was introduced in PLATO and developed in class. Extensive information on individual instructors usage is documented in the Fall 1975 Community College Users Report (Appendix S.6.1.1). Approximately 50% used PLATO during class time. PLATO usage from Fall 1974 to Spring 1976 is shown in Table 6.4.1. Spring 1976 usage by class and college is shown in Appendix 6.1.2.

Table 6.4.1

CUMULATIVE GENERAL CHEMISTRY USAGE
Fall 1974 - Spring 1976

	All Chicago Colleges	
	# Students	# Hours
Fall 1974 - Spring 1976	1308	6439
Fall 1975 - Spring 1976	1602	11024
Total	2910 students	17463 hours

6.4.5 Attitudes

The substantial progress in developing and implementing the chemistry curriculum can largely be attributed to a number of faculty members who responded to the attitude question in a Fall 1975 survey, teacher attitudes toward PLATO were:

attitude	negative	negative to neutral	neutral	neutral to positive	positive
Frequency	0	1	2	8	5

Among the twenty-one instructors who responded in the same survey, assessment of the quality of PLATO lessons was:

quality	very low	low	average	high	very high
frequency	0	1	6	13	

During scheduled class sessions an average of 1% of the students were unable to work during the Spring 1976 period .5% of the terminals were inoperative. Interruptions occured in 1.3% of the scheduled classes, but never required the cancellation of a class.

6.4.6 Recommendations

PLATO has been demonstrated to gain teacher commitment. It is anticipated that additional courseware will be developed and usage maintained on increased depending on terminal availability. There seems to be little cause to project problems with the use of PLATO in chemistry. One of the strengths of the program has been the test of transferability of the courseware.

6.5 COMMUNITY COLLEGE ENGLISH

6.5.1 Introduction

The Community College English Project presents an intriguing odessey in courseware development and implementation of computer-based (PLATO) instruction in language arts skills. Perhaps no other single subject encompasses as wide a range of learning outcomes, enjoys as extensive a course requirement status by all students, or reflects as many educational approaches among faculty members of the same department.

The effective use of language is universally regarded as the *sine qua non* of academic study as well as an essential functional skill in every career. Hence, the range of "English" courses in the participating colleges embraces reading, rhetoric, literature, and research. The problem of identifying the place of PLATO in the curriculum was difficult--not because of a lack of opportunity, but because of a lack of focus.

6.5.2 Curriculum Development

Faculty members at the participating colleges have contributed most of the available English lessons. These have been developed in wide a variety of ways.

Prior to the National Science Foundation contract, Barbara Geaither and Errol Magidson developed English lessons on the PLATO III system that were later revised for PLATO IV. Geaither and Magidson were members of a group of full-time released teachers from the City College of Chicago who worked at the University of Illinois Computer-based Education Laboratory during school year 1971-72.

In September 1972, Dr. Richard Vidabeck, Director of the NSF Community College Project, initiated efforts toward an English curriculum. With Tamar Abeliovitch Weaver, a CERL programmer, and Elise Spencer Gorum, a full-time released Chicago teacher, he began work on a sentence generator using transformational grammar.

Dr. Videbeck also taught a course for Chicago teachers in development of computer based materials. Three English instructors developed courseware by this method: Joe Vojacek, poetry and rhetorical logic; William Ibbs, paragraphing; and Robert Bator, research tools. Videbeck also directed the work of Paul Elliot and Bill Lucas, CERL staff members, in reading comprehension.

Concurrently during 1972, two part-time released Parkland College teachers, Doris Barr and Sally Wallace, separately developed lessons in sentence structure, usage, and grammar chiefly for their own students. They were trained and assisted in programming by Jim Kraatz and Judy Sherwood, PLATO Service Organization, CERL. Another independent project in vocabulary lessons was directed by Dr. Richard Scanlan of the University of Illinois Classics Department.

Thus, during the first eighteen months of the project (January 1972 - August, 1973) authors produced a limited amount of unrelated material. The lessons varied in subject matter and teaching style. Some lessons were not sufficiently pilot tested to eliminate programming errors and several were never completed.

In September 1973, an extensive review of the existing materials in English was conducted by Dr. Pauline Jordan, CERL English coordinator, assisted by University of Illinois graduate student staff members, and a committee of released time teachers. As a result, a language arts router system was designed to provide individualization and computer managed instruction in the skills areas.

Basically, this project consisted of identifying five topics within existing lessons: grammar, spelling, puncutation, vocabulary and usage. These topics were subdivided into skills categories. (See Appendix 6.5.1 for list of categories.) A pre and post test for each category determine students' proficency. Because the existing lessons frequently covered more than one category, the lessons were copied and divided into smaller segments of single instruction. The preparation of test items, programming of the router, and reorganization of the lessons was done during school year 1973-1974. Gary Michael adopted, expanded, designed and programmed the routing system from earlier work of the Elementary Reading Group.[1]

Any lessons ready for use which were not related to skills topics, as well as the original versions of the skills lessons, were described in hard copy in an English catalog prepared by Robert Bator, City Colleges of Chicago, in the summer of 1974. These lessons were available for use with the system router. (Appendix 6.5.2 lists the index of this catalog of English lessons.)[2] The catalog itself is Appendix S6.1.5 of this report.

The meetings held during 1973-1974 school year to review courseware were continued during the entire field test. The group took on formal status as PEEB (PLATO English Editorial Board) and was chaired by Robert Bator, a Chicago English teacher. Since 1974 the board has reviewed and

[1] Michael, Gary and Mary Sliger, LARS Instructor's Manual, CERL, University of Illinois Urbana, Illinois 61801, 1976.

[2] Community College English Lesson Index, CERL, University of Illinois, Urbana, Illinois 61801, 1976.

recommended changes to authors of existing lessons, set priorities for development of new lessons, screened lesson designs prior to programming, provided programming for English teachers unfamiliar with the TUTOR language, updated the English catalog, and provided training for new PLATO users. The board consisted of CERL PLATO staff members, community college PLATO personnel, and release time and volunteer English teachers.

6.5.3 Implementation

The use of PLATO in the English curriculum has depended substantially on the active participation of released-time authors, faculty members, and administrators. At the start of the field test in September 1974, volunteer users had been identified in each cooperating institution primarily because they had either designed and/or programmed courseware, or they had participated in the review of lessons by the English group during the previous year. The CERL English staff had distributed catalogs of lessons; and, together with the local PLATO site directors, trained teachers in the use of course records, instructor files, and the Language ARTS Router System. A marked degree of communication existed both via PLATO and through regualr visits to each school by the CERL PLATO English staff. This process was strengthened in the second semester of the field test by locating a full time CERL English staff member in Chicago.

Use of the Language Arts Router System was unexpectedly high in the first semester. The anticipated 250 students actually became 600 which resulted in a serious problem because of system limitation on storage of student data. The overall increased use of PLATO limited the capacity to store multiple lessons in short term memory. Feedback from teachers and students indicated directions were difficult, tests were too long, and especially that students not completing a test at the end of a scheduled session were required to repeat all of their previous work. These problems were addressed by, re-designing the routes, providing teachers with more options to review questions and instruction, and sequencing the tests between instruction units. The data storage problem was alleviated when the swapping memory at the computer was doubled in size to two million 60 bit words. New LARS options were continually developed according to input data on student use.

Because of the demand for courseware in the field of language skills, the favorable reactions of faculty members and students, and the services provided by the CERL English staff and the PLATO English Editorial Board, use of English materials continued to increase. Table 6.5.1 gives a record of participation during the field test. Typically, one of three class hour period each week was devoted to PLATO in-class use with the instructor present. Although instructors encouraged students to use PLATO out of class, neither assigned homework or extra credit was given for work on PLATO. It should be pointed out that the colleges are computer campuses with students almost always employed part time elsewhere, and that the available PLATO terminals were in constant use by other classes except for inconvenient student use hours such as late afternoon and very early morning. Courses using PLATO were English 100, remedial; English 101 and 102, the required first year rhetoric sequence; Reading 126, and several GED courses.

6.5.4 Data Collection

Although usage data was collected on each course by semester, it is

TABLE 6.5.1

USAGE BY INDIVIDUAL STUDENTS OF COMMUNITY COLLEGE ENGLISH LESSONS

Location	Fall 1974		Spring 1975		Summer 1975		Fall 1975		Spring 1976*		Total	
	#Stu	#Hrs	#Stu	#Hrs	#Stu	#Hrs	#Stu	#Hrs	#Stu	#Hrs	#Stu	#Hrs
School #1	395	1272	129	652	--		257	1043	212	761	993	3728
School #2	110	420	166	912	222	1736	154	493	342	1480	994	5041
School #3	160	541	399	949	178	564	555	2097	537	2002	1829	6153
School #4	298	650	373	627	158	724	399	1184	294	696	1522	3881
School #5	285	846	286	1126	63	295	181	1034	179	542	994	3843
TOTALS	1248	3729	1353	4266	621	3319	1546	5851	1564	5481	6332	22646

*This information is for the period January 1 - March 30, 1976 only.

difficult to interpret because of unique circumstances of both the course and the student themselves. These individual differences make comparison of the data very unreliable and the staff resource did not permit observation and documentation of usage.

An extensive usage study was made in the fall semester of 1975 and the reader is directed to consult that document for further information.[3] Also, a study was conducted for four weeks at Parkland College in Fall 1975, to determine the effect of PLATO Summarized Results usage on placement of students. The report of this study describes high levels of student acceptance of PLATO and indicates finding of a significant positive correlation between number of PLATO lessons completed and level of student performance when prior ability level (as measured by ACT score) is help constant ($r(80)=.237$, $p=.032$).[4]

In general, teachers using PLATO consistently mentioned the high motivational factor for underachievers. In a subject area where the range deficiency is so varied, the individualization and record keeping capabilities of PLATO were enthusiastically received.

An on-line notes file was used to collect comments on the materials. While this was initiated as a communication device to improve the courseware, it also served as a sampling of student opinions. (A representative selection of notes is given in Appendix 6.5.3).

6.5.5 Conclusions

In retrospect, it would have been more desirable to have concentrated in a more organized manner on a specified area of the English curriculum.

[3] Community College Users Report, CERL, University of Illinois, Urbana, Illinois 61801.

[4] Sliger, Mary and Irena Findelstein, PARKLAND COLLEGE FOUR-WEEK ENGLISH 100, CERL, University of Illinois, Urbana, Illinois, 1976.

The result of having many people work on many lessons resulted in promoting high usage and wide acceptance of PLATO; however, no single coordinated set of lesson material with empirical data collected in controlled experimental situations exists. The Language Arts Routing System was an after-the-fact attempt to coordinate use of existing materials rather than being designed from the ground up. The main objective of the project was to establish basic liaison with the cooperating institutions to assure their understanding of the project, acquaint them with the technology and courseware, and achieve a high level of institutional acceptance for a new teaching approach. This objective was substantially achieved.

6.6 COMMUNITY COLLEGE MATHEMATICS

6.6.1 Introduction

The community college mathematics project consists of 124 lessons amounting to more than seventy hours of instruction; this material has been implemented in all five of the participating community colleges with 51 instructors in 166 courses, involving almost 4,000 students and more than 16,000 hours of PLATO time. In addition, a criterion-referenced test study of lesson effectiveness was designed and carried out, and a general on-line data package was developed and used.

6.6.2 Curriculum Development

Prior to September 1973, some community college instructors had been trained in the TUTOR language and had developed mathematics lessons.

In Fall 1973, a full-time staff of content experts and programmers was formed at CERL for the purpose of coordinating and implementing mathematics courseware. The first step taken was the design of a Basic Mathematics Curriculum Plan and a procedure for lesson validation. A broad appeal was made to mathematics instructors during 1974 and early 1975 to participate in the actual design of PLATO lessons. Seven instructors provided lesson scenarios and fifteen helped in the setting of priorities for lesson development and in the critique of lesson designs; however, the design and programming of mathematics lessons was carried out by CERL staff. During the Spring of 1975, meetings were held in Chicago every two or three weeks involving CERL and CCC PLATO staff as well as mathematics instructors. They focused on usage problems, lesson design, and lesson review.

Appendix S6.6.1 provides a detailed list of all lessons with author, where and when produced, estimated time and design structure. Appendix 6.6.1 summarizes Appendix S6.6.1 by topic area. As these appendices indicate, the community college mathematics courseware includes lessons developed by the CERL Elementary Mathematics Group, by the community colleges, by the CERL community college mathematics staff, and by other PLATO authors.

The Catalogue of PLATO Mathematics Lessons for Community Colleges and Adult Education (Appendix S6.1.6) gives precise descriptions of the content of each lesson. The on-line lessons may be accessed by PLATO index lesson "mathcc".

6.6.3 Lesson Design

The list of structural features in Appendices S6.6.1 and 6.6.1 describes the structure of the lessons. Of the 124 lessons, 112 contain drill and practice sections; yet, every one is described as tutorial drill and practice, i.e., a tutorial sequence is provided for the student who needs help. Forty-five lessons use a model or contain a simulation or both. This provides a rough measure of how greatly the interactive graphic and judging capabilities of the PLATO system have been used. Eighty of the lessons are tutorial in nature, involving direct initial teaching of concepts. Twenty lessons use a driver that presents an index page and several sections of randomly generated problems with tutorial help sequences. Taken as a whole, the community college mathematics lessons should serve as a rich source of lesson models.

Since the PLATO system router has been available during all of the usage period of this project, it has not been necessary for the Community College Mathematics Group to develop a router of its own.

Extensive efforts in data collection and analysis have accompanied the development of mathematics courseware. Tamar Abeliovich Weaver of the Community College Mathematics Group has worked with the PLATO Educational Evaluation and Research Group and Educational Testing Service in the development and testing of data routines.

6.6.4 Implementation

Math project staff began making regular trips to the sites in the Fall of 1973 to meet the instructors and learn more about the courses and students. Initial reactions from math faculty were mixed. Several instructors at each of Schools #1, 2, and 3 showed early interest in PLATO and these three schools have consistently been the strongest PLATO sites for mathematics. Mathematics faculty at School #4 were wary of PLATO and remained uninvolved until Spring 1976. The mathematics department at School #5 was cordial, attended several meetings about PLATO, provided a wealth of information about course syllabi and class schedules but produced no strong PLATO users in mathematics.

During the Spring and Summer of 1974, five instructors were given released time to work on PLATO. The instructor from School #1 was the lead instructor in mathematics, had undergone training in TUTOR programming sometime prior to September 1973, had programmed a PLATO lesson, and intended to continue with the development of lesson material. He was generally supportive of PLATO, but left the school in June 1975. The other four released time instructors were new to PLATO and were asked to review lesson material and to develop an implementation schedule for the use of PLATO lessons in their own courses. One of these four instructors wrote a brief critique of the lesson materials which was largely negative. This instructor has not used PLATO at all. The other three released time instructors were from the same school. They have each used PLATO more than one semester; they each took the PLATO extension course (although one of them did not complete the course); and a schedule was developed which integrated PLATO lessons into the algebra course.

During this same period of time (Spring and Summer of 1974) meetings were held with several non-released instructors. Two instructors at School #1 worked with CERL staff in revising the design of the signed numbers lessons so that these lessons would better fit into the algebra courses there. At School #2, three instructors were particularly interested in being able to use PLATO in their drafting and machinist courses. A careful examination was made of their mathematics programs and design specifications were drawn up for a series of trigonometry lessons. Unfortunately, a number of administrative changes occurred near the end of the summer which delayed the implementation of these programs for nearly a year.

The Fall semester 1974 showed 23 courses, 574 students and 1,520 hours of PLATO mathematics usage. By the end of the two-year field test, there had been 166 courses, 3,823 students and 16,071 hours of usage. In order to illustrate the pattern of growth throughout the field test, Appendix 6.6.2 provides a breakdown of this usage by school and by semester/quarter.

The lowest usage occurred during Fall 1974. In addition to a small base of users during that first semester/quarter, not all terminals had been installed, there were hardware problems, and there were stringent limits on storage in the swapping memory. These problems were virtually negligible during the 1975-76 year and with two exceptions in the Fall of 1975. The mathematics department at School #1 called off plans for running a criterion-referenced test study in their intermediate algebra courses and the Fall semester was spent in planning the same study for the spring. Consequently, the number of students using PLATO mathematics at School #1 during the Fall of 1975 dropped to the level of Fall 1974 and the average time on PLATO sank below three hours per student. The other exceptional case was School #2. Instructors from Schools #2, 3, 4, and 5 went on strike for several weeks at the beginning of that semester, and PLATO usage suffered most severely from this at School #2. The number of PLATO students dropped to half the original number for School #2 and the average time on PLATO was half what it was during the previous period. Mathematics usage at both Schools #1 and #2 bounced back up during the Spring 1976 semester. Although PLATO mathematics activity remains low at School #4, several instructors from the mathematics department became interested in PLATO during the Spring 1976 semester. Until then, PLATO mathematics usage at this school was due only to Learning Center and GED instructors. School #3 has consistently had the highest number of students, and School #2, although it is the smallest school, has consistently had the highest average time per student.

The pattern of liaison in the math project has been fairly consistent throughout the field test: frequent personal contacts with instructors; constant feedback from instructors and site personnel on the lesson material; and cooperative lesson review and lesson design work. In the Fall of 1975 "Student Guides to PLATO" were produced that keyed PLATO lessons to the exact section and page of the course textbook. Instructors and students both reacted very favorably to these student guides developed for four courses at Schools #1, 3, and 5. The regular meetings (discussed above in Curriculum Development) also contributed to the implementation program.

Most of the mathematics usage has occurred in seven different types of mathematics courses:

I. Related Mathematics for Vocational Students. This type of course occurred at School #2 only. The students were all enrolled in a vocational course such as machinist, welding, stenography, drafting, etc. Each of these courses included five to ten hours of "related education" per week in math.

II. Algebra. This is generally the first algebra course the student can take in college. It begins with set theory, signed numbers and simple algebraic notation and continues through algebraic expressions and equations. Although the syllabus includes such topics as graphing straight lines and solving quadratic equations, these topics are often not covered in the courses.

III. Intermediate Algebra. This course may properly be described as "College Algebra." It includes a detailed study of graphing straight lines, 2X2 and 3X3 systems of linear equations, graphing quadratics, and solving quadratic equations and fractional equations.

IV. GED Math. The mathematics classes in the GED program comprise this type. Although these classes were held in Schools #3 and #4, the instructors and the classes are not part of the mathematics departments.

V. Preparatory Mathematics. This course is designed for two-year college students who are deficient in basic mathematical skills. It generally begins with whole number arithmetic and decimals and fractions and, in some cases, includes algebraic expressions and simple linear equations.

VI. Technical Mathematics. This course is designed for two-year college students who are concentrating in a technical or vocational area. It reviews fractions, decimals, and percent as well as algebraic operations and equations, and introduction to trigonometry. (NOTE: One difference between course types I and VI is that the Type I courses select only those math skills which are directly practical in the students' own area; whereas a Type VI course generally has a more extensive syllabus which is fixed for all students.)

VII. Learning Center. The mathematics instruction at the learning centers is usually run on an individual student basis. Some of the schools staff the learning centers with regular faculty members, other schools have non-faculty Learning Center personnel. A learning center student usually uses PLATO on referral from a learning center instructor. Usually the learning center instructor accompanies the student to the PLATO room.

In addition to the seven major course types, there has been a small number of PLATO lessons in a number of other types of courses which, for this report, have been labeled "Miscellaneous Courses."

VIII. Miscellaneous Courses.

a. Adult Education Math Course -- remediation in fractions, decimals, percent, signed numbers, elementary algebra.
b. Algebra II -- follows Intermediate Algebra.
c. Trigonometry.
d. Experimental PLATO course -- not connected to a department course.

Appendix S6.6.2 gives a detailed list of the 166 PLATO courses. In addition to course type, school, instructor, number of students, number of hours and average hours per student, there is a rough indication of the scheduling pattern and also whether or not the instructor provided a PLATO hand-out to his students.

It was decided as a matter of convenience to schedule users during a regular class period. Aside from the inevitable conflicts that arose during the peak hours for scheduled classes, this arrangement was particularly deleterious for mathematics, since much of the lesson material was designed to be used in connected sequences of class sessions. For example, the lesson package on plotting points and graphing straight lines is designed to be used in six consecutive class sessions. The same is true of the fractions, decimals/percent, signed numbers, solving linear equations, fractional equations and simultaneous equations materials. Of 156 courses, twenty were scheduled in consecutive class sessions; 97 were scheduled at intervals of once a week; and 39 for optional student use.

Comparison of Usage by Scheduling Pattern

Scheduling Pattern	# Of Courses	# Of Students	# Of Hours	Average Hours Per Student
1/week	97	2,502	10,615	4.2
sequential	20	417	2,902	7.0
optional	39	724	1,964	2.7

Apparently, a number of the 1/week courses did not actually use PLATO every week. Since it was rare that instructors using the optional scheduling took PLATO performance into account in grading their students, the low average hours per student are not surprising.

Appendix 6.6.3 summarizes the usage according to course type; Vocational, Algebra, Intermediate Algebra, and GED account for about 80% of all the usage. These were the course types for which the greatest amount of liaison work was expended and the enrollment in these four types of courses is relatively much higher than the enrollment in the other mathematics courses.

A history of the 51 mathematics instructors involved in this project is given in Appendix S6.6.3. Twenty-six of these instructors used PLATO more than one semester, and 44 of the instructors used PLATO in more than one course.

Appendix 6.6.4 shows PLATO time distributed by topics and lessons based on ten vocational courses during Spring 1976, four algebra courses during Fall 1975, three algebra courses during Spring 1976, four intermediate algebra courses during Fall 1975, and three intermediate algebra courses during Spring 1976. Appendix 6.6.4 gives the topics and lessons used in each group of courses, the amount of usage in each lesson and topic and the proportion of total usage in each topic. Within each topic, the lessons are listed not in their logical order, but in rank order according to number of students using the lessons. The lesson usage data in Appendix 6.6.4 was gathered from the on-line data package developed by the Community College Project.

6.6.5 Attitudes

Data gathered on fifteen mathematics instructors during the Fall of 1975[3] indicated that fourteen of the fifteen rated the difficulty level of the mathematics lessons as "appropriate", one instructor rated the lessons as "difficult" -- none rated the lessons as either "too difficult" or "easy". One mathematics instructor out of fourteen rated lesson quality "very high"; seven rated lesson quality as "high"; five rated lesson quality "average", and one rated lesson quality "low". (See PLATO Evaluation Report, R. A. Avner and E. Avner, April 19, 1976.)

The consensus across most of instructors who used PLATO during this study seems to be that the PLATO material currently available is capable of providing good drill and practice lessons and can be used profitably for presentations involving screen graphics, but does not compete with the human instructor in the initial teaching of concepts. Criterion-based teaching is not standard in community college mathematics classes. Most of the courses in which PLATO was used were run in the traditional lecture style (although the vocational courses and the learning centers and a few other are generally

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3 D. Alpert and P. Jordan, The Community College Users Report, Fall 1975, Computer-based Education Research Laboratory, University of Illinois, Urbana, Illinois, 61801 (Appendix S6.1.1 of this report.

individualized by the use of workbooks), and many instructors felt that extensive PLATO lessons sequences that are criterion-based do not fit well into their classes. The only information on student attitudes available at this time is a file of on-line student comments. During the period from September 24, 1975 to May 29, 1976, 915 student comments were collected. The comments were divided into two groups: One group consisting of all comments which concerned the mathematics lessons (including technical comments) or PLATO (793 comments), and the other group consisting of all other comments (122 comments in this group). The comments in the first group were subjectively rated as expressing positive, neutral, or negative attitudes toward the mathematics lessons or PLATO. The breakdown of these comments was as follows:

Positive:	490	(62%)
Neutral:	43	(5%)
Negative:	26	(33%)

In order to give some sense of the kind of comments that were collected, a number of typical examples are given below:

Positive: "PLATO you are the best teacher I ever ran into. You seems to understand that it takes time to catch on, which I think is the way a teacher should do. Thanks."

"the lesson is fantastic more of it."

"this was a very good way to teach this lesson. PLATO taught me this lesson easier than my teacher did. I understood it much better."

"collecting terms i really liked the lesson. The lesson was easy. This is a very good machine to work with"

"this is a very good lesson i had to think on this one"

"the lesson was very easy it help me a lot with my fractions i like doing the lesson very much"

Neutral: "I thought it was confusing at times. PLATO does not always explain thing clearly. However: PLATO does a much better job that the book. he can tell you where you are going wrong and help you correct it."

"I think that the lesson I just completed was very similar to the other one before this."

"First of all I would like to say part of the lesson was easy the other was kind of hard"

"I fell that the lesson I just did very helpful although it was very, very boring"

Negative: "Very confusing questions."

"this lesson was entirely too hard for me to understand. I hope that we can go over this in class before we have an examine."

"I did not understand give me some thing easy"

"Too easy"

"who ever wrote this lesson didn't make it clear"

6.6.6 Effect On Student Performance

In an attempt to measure the effectiveness of PLATO, the mathematics group designed a number of criterion-referenced tests on material that was covered by sequences of PLATO lessons (Appendix S6.6.4). A study of the straight-lines lessons was carried out during the third and fourth weeks of the Spring 1976 semester in the intermediate algebra course at School #1. During a period of two weeks, classroom work was replaced in three sections by sessions on PLATO and PLATO was not used in the fourth section. Criterion-referenced pre- and posttests were administered in all sections before and after the two week period of instruction. Matching pre- and posttest scores were obtained for 51 PLATO students and 22 non-PLATO students. The topic of simultaneous equations was also covered during the instruction, but that lesson sequence was not evaluated in this study. Six fifty-minute PLATO sessions were held in each of the three class sections which used PLATO and the average time spent per student was 7.9 hours. This figure is based on the data for the 51 students who took both the tests and is 2.9 hours more than the five hours available during scheduled PLATO sessions. Even in this two week time period of the study, there was considerable variation in the amount of time PLATO was used by the students (Apendix 6.6.5).

There were eight lessons in the straight line sequence and eight lessons in the sequence on simultaneous equations. The number of students who completed a given number of lessons in these two sequences is shown in Appendix 6.6.6. Although there was marked variation in the time spent, most of the students finished the assigned lessons.

The average total score on the straight line post-test was 74% for the PLATO students and 72% for the non-PLATO students which represents no statistically significant difference. In order to determine whether initial differences among the students may have affected these results, an analysis of covariance was carried out for one PLATO and one non-PLATO section. Both of these sections were taught by the same instructor who made available the results of a review test given before the study began. Based on the pretest and review test scores, the analysis of covariance yielded estimated means of 84% for the PLATO section and 67% for the non-PLATO section, a statistically significant difference in favor of the PLATO section.

The finding that when some of the initial differences between the PLATO and non-PLATO students are taken into account, the performance of the PLATO students was higher than that of the non-PLATO students supports the conclusion that PLATO provided effective instruction for the target population.

6.6.7 Concluding Remarks

In the course of this project, a wide variety of mathematics lessons have been developed and implemented. They vary in content, style and structure and they have been implemented in a number of educational settings from vocational and GED classed through Algebra II and Trigonometry. It has been shown that mathematics instructors are willing to try out new educational technology and are willing to participate in the development of optimal implementation strategies. Community college students would benefit from sound criterion-based PLATO curricular materials, and such developmental work should continue. This record is offered in the expectation that future projects of this sort would profit from the experiences and findings presented here.

The production of high quality lesson material is difficult. If effective lessons are to be produced and if the full capabilities of the PLATO system are to be realized, considerable expertise in instructional design and TUTOR programming are needed. A thorough-going effort at measuring the overall effects of the lesson material must go hand-in-hand with the lesson production work. Considerable experience has been gained in the application of on-line data analysis to the problems of lesson effectiveness and implementation. One successful criterion-referenced test study of lesson effectiveness was completed. These efforts barely have scratched the surface, but they provide sufficient justification for continuing the work.

7. UNIVERSITY PHYSICS

7.1 SUMMARY

The main output of the university physics project is about a hundred hours of lesson materials which have been tested with hundreds of students at several different colleges and universities. Brief descriptions of these lessons are given in section 7.13. Another important outcome is that much experience was gained in how to integrate PLATO lessons into a course which also has other activities. Student attitudes as measured by a questionnaire were found to be quite positive. The same final exams were given to students in PLATO and non-PLATO courses, and no differences were seen in the distributions and means of the exam scores, even though there was a decrease in formal class time. Some follow up studies were also made to look at performance in later courses, and no differences were seen in later exam scores or letter grades. These effects are discussed.

7.2 AUTHORS

Faculty and staff of the Department of Physics at the University of Illinois, Urbana, who have been involved with writing PLATO physics lessons include Prof. Bruce Sherwood, Mr. Dennis Kane, Ms. Carol Bennett, Prof. James Smith, Prof. David Sutton, and a number of graduate students. Other writers include Prof. Donald Shirer, Valparaiso University, and Prof. Ed. McNeil, University of Illinois at Chicago Circle. This report is the responsibility of the Urbana group.

7.3 HISTORY AND SETTING

Development of PLATO physics courses began in 1970 on the PLATO III system. A first experimental group of ten students was taught with the aid of these materials in 1971. As the PLATO IV system began to develop, ten new terminals were placed temporarily in the Physics Building. An addition of university physics to the NSF contract provided a total of thirty terminals on a permanent basis to the physics department, and the department later bought one more terminal. The department gave up a large room, which had formerly been a stockroom, and with university and departmental funds this room was remodeled to house the terminals. This cluster of thirty-one terminals makes it possible to run scheduled PLATO classes, since most physics courses are divided into sections of twenty to twenty-five students. The physics department facilitated the writing of new materials and the conversion of materials from PLATO III to PLATO IV by partially funding some senior staff and by assigning graduate-student teaching assistants to PLATO-related activities. The department at a very early stage included PLATO activities in its long-range planning and budgeting within the university.

The availability of the physics PLATO classroom has made it possible not only to develop and test individual lessons but also to gain experience in integrating these materials with regularly scheduled classes on a large scale. Except for other PLATO projects of similar scale, few implementations of computer-based instruction have been large enough to affect large numbers of students and to warrant large-scale production of lessons materials. Many physics departments have their students write computer programs in order to study complex phenomena, but very few departments have attempted to teach directly through an interactive computer system. An exception is Alfred Bork's project at the University of California at Irvine, which combines computational use of the computer with significant amounts of direct instruction by means of the computer. At the University of Illinois, exploitation of PLATO as a computational tool within the physics department has been limited mainly to providing various calculators and function plotters, which are used extensively by graduate students and faculty in their research work. The focus of undergraduate curriculum development at Illinois has been on direct instruction, because the use of the computer as a computer has been well studied and implemented in many other places.

7.4 LESSONS

Short abstracts of existing lessons are given in section 7.13. These materials constitute the major output of this project. They are already being used extensively not only at the University of Illinois in Urbana and at Chicago Circle but also at other colleges and universities, including the University of Arizona, Carnegie-Mellon University, and Valparaiso University. Some use also occurs in several medical schools and community colleges. It appears that this year additional sites on the Urbana PLATO system will begin using these lessons, including the University of Delaware. Institutions on Control Data Corporation's PLATO systems who are hoping to get access to the materials include the University of Colorado and the University of Quebec. Florida State University has included physics in a proposed test of PLATO courseware they hope to carry out.

Most of the PLATO physics lessons have been written by people in Urbana.

It seems probable that the major factor inhibiting large-scale lesson production at the other sites is the relatively small number of terminals at those sites. A physics professor is unlikely to make a large personal investment in writing PLATO lessons if the number of terminals is insufficient to deliver the lessons to his or her students. A related point is that having only a few terminals may inhibit the growth of a supporting PLATO culture, in terms of having a critical mass of teachers and students interacting locally with each other to generate ideas and to trade experiences. On the other hand, even small numbers of terminals permit faculty to use existing lessons with some students with little investment of time or effort. So while it is observed that at smaller PLATO sites not many new lessons are written, existing lessons are used extensively.

The materials described in section 7.13 fall into three main groups: classical mechanics for engineering and science students (normally taken concurrently with calculus in the freshman year), introductory modern physics with waves and optics for engineering and science students (the final semester of a three-semester sequence in Urbana, of which the classical mechanics course is the first semester), and various materials for junior, and graduate courses, particularly in quantum mechanics and nuclear physics. In the next sections are descriptions of how these lessons are used in courses at Urbana. At other PLATO sites the same lessons are used in a variety of ways, in varying degrees of integration with other aspects of courses, including simply making the lessons available to student as a library resource essentially divorced from any particular course.

7.5 CLASSICAL MECHANICS

The classical mechanics course is offered at Urbana in both PLATO and non-PLATO versions, with the PLATO version handling about one-third of the total enrollment (total enrollment reaches almost one thousand students in the spring semester). In the non-PLATO version, students are scheduled to attend every week two one-hour lectures, a two-hour small discussion class led by a faculty member or graduate student, and a two-hour laboratory led by the same person. Only five or six laboratory exercises are help during the fifteen-week semester, and during the other weeks the laboratory period is used for additional discussion. In the PLATO version of the course, there is only one lecture, and the discussion class is scheduled in the physics PLATO classroom with the instructor present to handle individual questions that may come up as the students work through the PLATO lessons. In the non-PLATO course homework problems are usually not collected and graded, partly because of the large amount of manpower required to do so. In the PLATO version, however, students turn in homework answers to PLATO for grading. These homework scores automatically go into an on-line gradebook, and the scores form one component of the overall course grade. All students work the same problems but with different numerical factors chosen by PLATO. Students also earn course credit by completing instructional lessons, most of which are about an hour long and contain mastery quizzes. In both versions of the course, there are three one-hour closed-book exams and a three-hour closed-book final exam. These exams involve solving mechanics problems which are of a difficulty comparable to the assigned homework problems or a little easier.

The on-line gradebook holds not only information on PLATO activities, including lesson completion and homework score data, but instructors also enter off-line grades coming from lab reports and exams. Students can look at their own grades and can also see graphical distributions of how they stand with respect to other students in the course. Another unusual component of the PLATO course is an on-line forum in which students and instructors can discuss aspects of the course. Problems from old exams are available on-line for review, and PLATO tells students their scores and times for these practice exams. For some lab experiments, there are on-line aids or simulated experiments to help with the lab reports.

Students are expected to complete instructional lessons and homework problems on a schedule keyed to the weekly lectures. As an additional inducement to keep on schedule and as an additional indicator of what work is required to be on schedule, students who complete their PLATO work ahead of time are permitted to play computer games (but only in the physics classroom and only if there are adequate extra lesson space and terminals). This procedure has made a remarkable improvement in student pacing -- almost all students now keep up to date. In the past, almost all students did eventually turn in all the work, but not on schedule.

While students use PLATO on a scheduled basis two hours per week, they are expected to spend at least one more hour per week on PLATO, which would compensate for the fact that the PLATO course has only one lecture per week instead of two. By actual measurement, the students spend a little more than four hours per week on PLATO on the average. (There is, of course, a wide spread across the students in the number of hours per week spent using PLATO.) It is not known how many other non-PLATO study hours per week are spent by the student, nor is it known how many hours per week of study are spent by the students in the non-PLATO course.

The need to provide four hours of terminal time per week per student determines the number of terminals required to teach such a course. In most institutions, terminals could probably be used about sixty hours per week, in which case each terminal could serve fifteen students. A classroom of thirty terminals could handle 450 students in one course.

7.6 INTRODUCTORY MODERN PHYSICS (WITH WAVES AND OPTICS)

For this third semester of the introductory physics sequence for engineering and science students, there exist many PLATO lessons which illustrate the important concepts and phenomena. The emphasis of most of these lessons is less on direct instruction and more on providing the student with tools, including simulated experiments, which can illuminate what are otherwise abstract notions. Because of concentration on testing the classical mechanics course, less work has been done in structuring a course based on these modern physics materials. One way in which they have been used is as optional, supplementary resources made available to students. During the summer of 1976, closer integration was achieved, with the lessons, homework exercises, laboratory aids, and exam reviews all made a more integral part of some sections of the course. In addition to such week-by-week uses, it is now the case that one lab experiment in the regular course each semester is a PLATO exercise on wave functions in potential wells. The full enrollment in the course is handled by tight scheduling and by having two or three students work together as a group at each terminal.

7.7 UPPER-LEVEL PHYSICS COURSES

Many Urbana physics courses at the junior, senior, and graduate levels use PLATO materials on a regular basis. In both quantum mechanics and nuclear physics, many faculty have used PLATO as a laboratory by writing up exercises for students to perform with the aid of existing PLATO materials. Students turn in a lab report based on their work. In most cases, the PLATO materials have been written by staff in response to and with the suggestions of the concerned faculty members. In addition to such assigned w , many upper-level and graduate students use PLATO calculators and function plotters in their course work and in their research. The department provides a Polaroid camera on demand to make photos of important graphical results.

7.8. STATUS OF DEPARTMENTAL INVOLVEMENT WITH PLATO

PLATO is now an integral part of the Urbana physics department. While few faculty have written PLATO lessons, many have used PLATO in one mode or another. Some courses make regular use of PLATO, while others use PLATO occasionally. The department encourages faculty involvement in various ways, including budgeting for equipment and staff and providing space. The head and associate head of the department have maintained a long-term commitment to explore and exploit this new technology. Faculty are being rotated through courses involving PLATO in order to increase the number of faculty with direct experience with PLATO. The regular weekly colloquium series has had a talk related to PLATO every year or two for the last five years.

7.9 EVALUATION

While the main product of this work is the lessons themselves, both subjective and objective evaluations of the PLATO physics materials have been attempted. Subjective evaluations include student questionnaires and comments by instructors. Objective evaluations include giving the same final exam to both PLATO and non-PLATO students. Attempts at such evaluations have so far been limited to the area of classical mechanics, which is the course that has been most heavily developed and which has had large numbers of students.

At the end of the spring semester, 1975, students in the PLATO-based mechanics course were asked whether they would choose a PLATO or non-PLATO version of the following course, if both were available. They were also asked whether the PLATO course should continue to have lectures, and whether a single one-hour lecture per week is sufficient (the non-PLATO course has two one-hour lectures per week).

For technical reasons, these questions were asked during the last lecture, which was attended by 134 of the 202 students enrolled in the course. It is impossible to estimate the bias introduced by having responses only from the two-thirds of the students who came to the last lecture.

The results of the questionnaire were as follows:

Choose PLATO course:	100 yes
	27 no
	7 no response
Retain lectures:	120 yes
	3 no
	11 no response
One lecture adequate:	75 yes
	48 no
	11 no response

The 100 students favoring a PLATO physics course gave general reasons such as "understand better", more pleasant", and "more interesting". Specific reasons for their preference included:

work at own rate, self-paced (15 responses)

forces me to do more work and keep up (11)

cuts down on the amount of work required (5)

course less dependent on instructor, who may be poor (5)

miscellaneous (1 each) -- more personal attention, good for review, derive formulas for yourself, unifies a lecture-discussion course, friends in non-PLATO course wanted to switch to PLATO

The 27 students who would choose a non-PLATO physics course gave the following reasons for their preference:

prefer human instruction, more discussion (14 responses)

PLATO work takes too much time (6)

want the discipline of weekly quizzes, feel PLATO lets them get by with little work (3)

violently dislike PLATO (no specific statement) (3)

access to PLATO difficult (not enough terminals, too far from dorms) (1)

Perhaps the most interesting aspect of these student evaluations is the large differences in perceptions of how much work is required in the PLATO course, together with differing feelings about whether more or less work is a good thing. It should be pointed out that since the mechanics course is the first in the introductory physics sequence, these students had not yet had a non-PLATO physics course to compare with.

Another important subjective evaluation is that a growing number of institutions are using the materials. The lessons have been designed to be modular in nature, which has permitted different institutions to use the lessons in differing ways. At Valparaiso University it was found possible to eliminate from lectures certain topics which are covered by PLATO lessons. Chicago Circle reports being able to use the same lessons in different courses. Carnegie-Mellon University and the University of Arizona offer the lessons as an extra supplement, and students who use these aids average one to one-and-a-half hours a week of PLATO use. The Albany College of Pharmacy reports that their students find the materials useful, even though the lessons were not designed for that audience.

One objective measurement consists of giving the same final exam to PLATO and non-PLATO students. This has been done several times, and both groups have always shown essentially the same distributions and means of the exam scores. Fig. 7.1 shows a page-by-page comparison of one such exam (solid bars for the PLATO students and open bars for the non-PLATO students give the scores on each page, plus or minus the rms deviations). The differences are not statistically significant. Studies are proceeding to determine whether the populations differ in any significant way, since the PLATO and non-PLATO sections are identified as such in the university timetable, and if there are not other scheduling conflicts the student can choose which course to enter. At this time there is no evidence that the groups differ in ability or background.

A pessimistic interpretation of the equivalence of the final exam scores is to say that despite the PLATO tutoring and despite the fact that almost all the PLATO students turned in all the homework problems (whereas it is known that in the non-PLATO course most students, in fact, do not do many of the assigned homework problems), nevertheless the PLATO students could not do any

Median, average, rms for all sections by page number

PLATO (14 secs, 133 studs)

pg)	med	ave	pos	rms
1.)	12	8.2	24	8.055
2.)	15	16.4	25	7.770
3.)	16	14.2	30	9.614
4.)	12	10.4	24	6.142
5.)	28	26.3	38	9.363
6.)	12	10.7	30	7.708
7.)	10	7.7	20	7.641
8.)	6	8.2	16	5.941
9.)	0	4.0	30	7.391
10.)	10	9.6	20	6.598
11.)	0	2.6	20	5.584
12.)	8	9.2	28	4.456

Non-PLATO (33 secs, 276 studs)

pg)	med	ave	pos	rms
1.)	0	6.7	24	7.751
2.)	15	14.5	25	8.062
3.)	13	13.8	30	9.489
4.)	12	8.4	24	6.789
5.)	22	22.2	38	10.214
6.)	12	9.0	30	7.963
7.)	0	5.0	20	6.051
8.)	6	6.3	16	5.530
9.)	0	4.9	30	7.786
10.)	5	8.0	20	6.298
11.)	0	3.7	20	6.198
12.)	8	8.1	28	5.313

ave ± rms (%), solid = left, box = right.

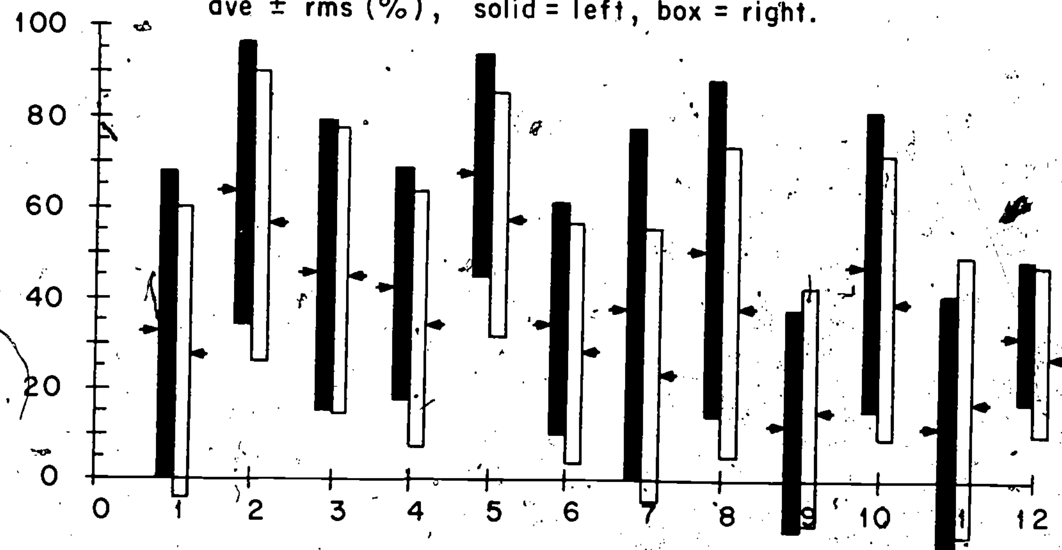

Fig. 7.1 Final exam scores of PLATO students (solid bars) and non-PLATO students (open bars).

better on the final exam. An optimistic interpretation of the result is to say that although the PLATO students had only one lecture a week, although the discussion class was essentially taken over by PLATO (but with an instructor present to handle questions), and although the average student only spent two non-scheduled PLATO hours of study per week in this difficult course, nevertheless the PLATO students did as well on the final exam as the non-PLATO students. A realistic interpretation might be that it has always been almost impossible to see differential effects on final exams resulting from differentials in the form of instruction. As an example, after many measurements it is apparently still an unsettled question whether large lecture classes are better than small discussion classes, or vice versa, in terms of final exam scores. More generally, there seem to be few examples in higher education where large effects on examination scores have been observed following changes in teaching techniques.

Within the PLATO mechanics course, various correlations have been examined, such as exam scores versus homework problems completed or exam scores versus instructional lessons completed. The only significant correlations that have ever shown up have been between one exam and another. That is, if the student does well on the first exam, he or she will almost certainly do well on the second, third, and final exams. The issue is somewhat muddied in recent semesters by the fact that few students fail to turn in all the assigned lessons and homework, so that there is little spread to correlate against. However, these results also obtained in earlier semesters (before the carrot of computer games), when at the time an exam was taken many students had not yet turned in work supposedly relevant to that exam.

Since the exam problems are quite similar to the homework problems, one would expect that doing the homework problems should help in taking an exam. However, the student can get help on the homework problems from the textbook, from the instructor, and from other students, whereas during the closed-book exam the student is completely on his own, under time pressure, and facing new problems. The course really has two rather different components -- weekly assigned work (lab reports, PLATO lessons, and PLATO homework) and exams, the latter differing from the former in being a different kind of measurement of the student's work. We believe the weekly assigned work is just as important as the exams, even if we cannot measure (by exam) all aspects of the benefits of the weekly work. It is also true that a student who performs well on one component and poorly on the other will be given a passing grade. Only if the student performs poorly on both course components will he or she be failed.

While it was convenient to correlate exams and homework in the PLATO course, given that the data are all on-line, it seems likely that the lack of correlation between these two activities is not limited to PLATO-based courses but is an effect which would hold true in any similar physics course.

It might also be pointed out that the PLATO course shares some aspects of "self-paced" or "personalized" instruction. The course is divided into modules of instruction, and mastery-level performance is required on lessons and homework to pass from one module to the next (except that students are permitted to move ahead without mastery if they get too far behind, but they do normally go back and complete the work later). If it were not for the four exams, which destroy our illusions, we would give almost all students the grade of "A", since almost all students do, in fact, complete modules on time at a mastery level.

Some longitudinal studies have been attempted. Correlations of grades and exam scores have been made for PLATO and non-PLATO mechanics students between the mechanics course and later courses, including following physics courses and including advanced mechanics courses in the Department of Theoretical and Applied Mechanics. While in some cases the statistics are poor, it can be said that none of the comparisons show any significant correlations other than the fact that good performance in one course is strongly correlated with good performance in another course. In other words, there is at this time no hard evidence that taking the PLATO course either helps or hurts the strong or weak student more than the non-PLATO course does in terms of doing well in a later course.

Fig. 7.2 shows final exam scores in Physics 107, the follow-on course to Physics 106, the classical mechanics course. Distributions are shown for students who had the PLATO and non-PLATO 106 course. The distributions and means are essentially identical. Similar comparisons of course letter grades are shown in Fig. 7.3. Similar comparisons of final exam scores and letter grades in an advanced mechanics course in Theoretical and Applied Mechanics are shown in Fig. 7.4 and Fig. 7.5. Again, there is no noticeable difference between PLATO and non-PLATO students. Just to give an example of a situation where high correlations are observed, Fig. 7.6 and Fig. 7.7 show scatter plots of Physics 107 final exam scores versus Physics 106 final exam scores, for PLATO and non-PLATO students. It is seen that performance on one exam is highly correlated with performance on another exam for both sets of students.

7.10 PROBLEMS IN USING PLATO

The major disadvantage or difficulty experienced with PLATO in physics

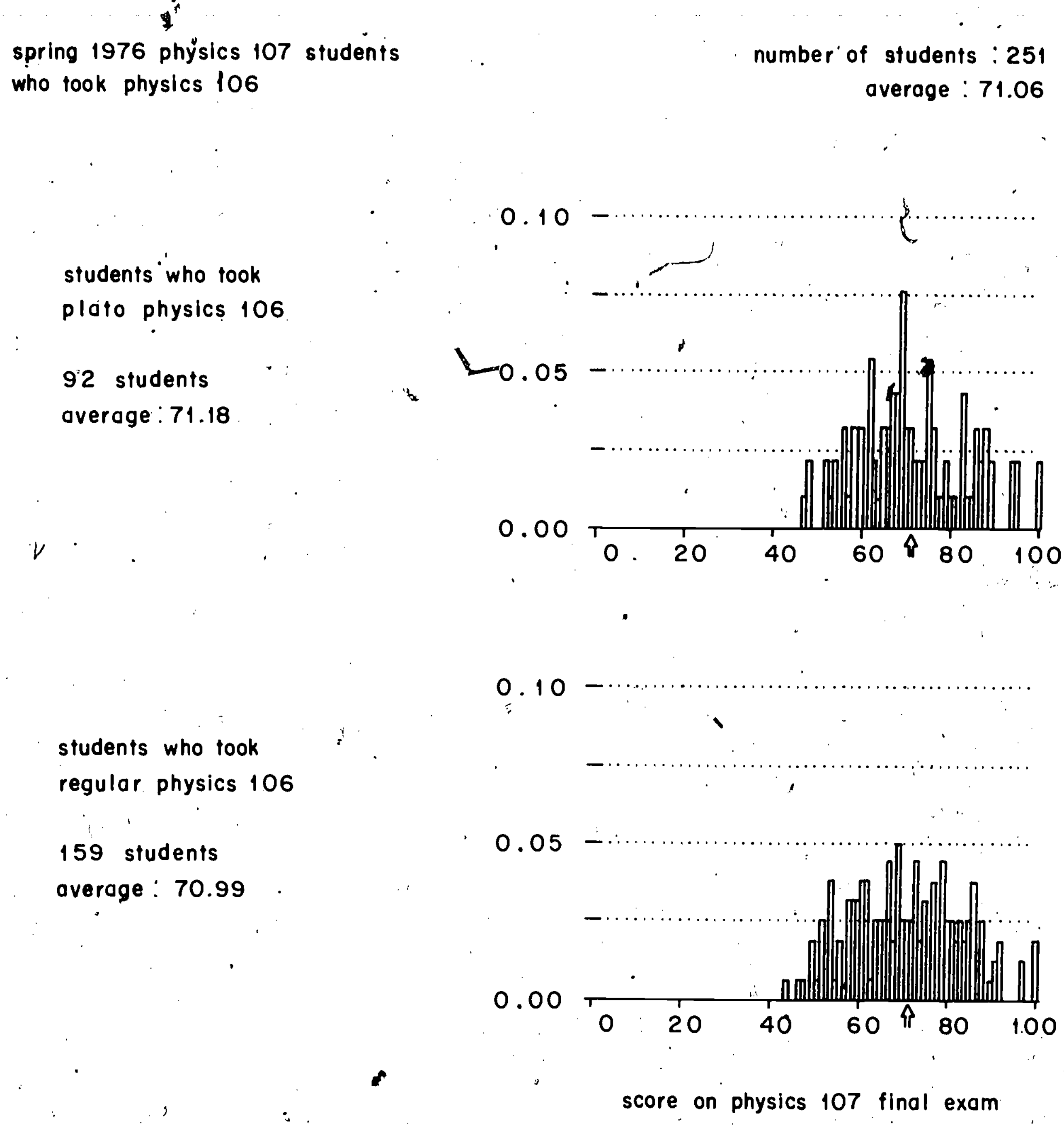

Fig. 7.2. Final exam scores in Physics 107 for students who took PLATO and non-PLATO Physics 106.

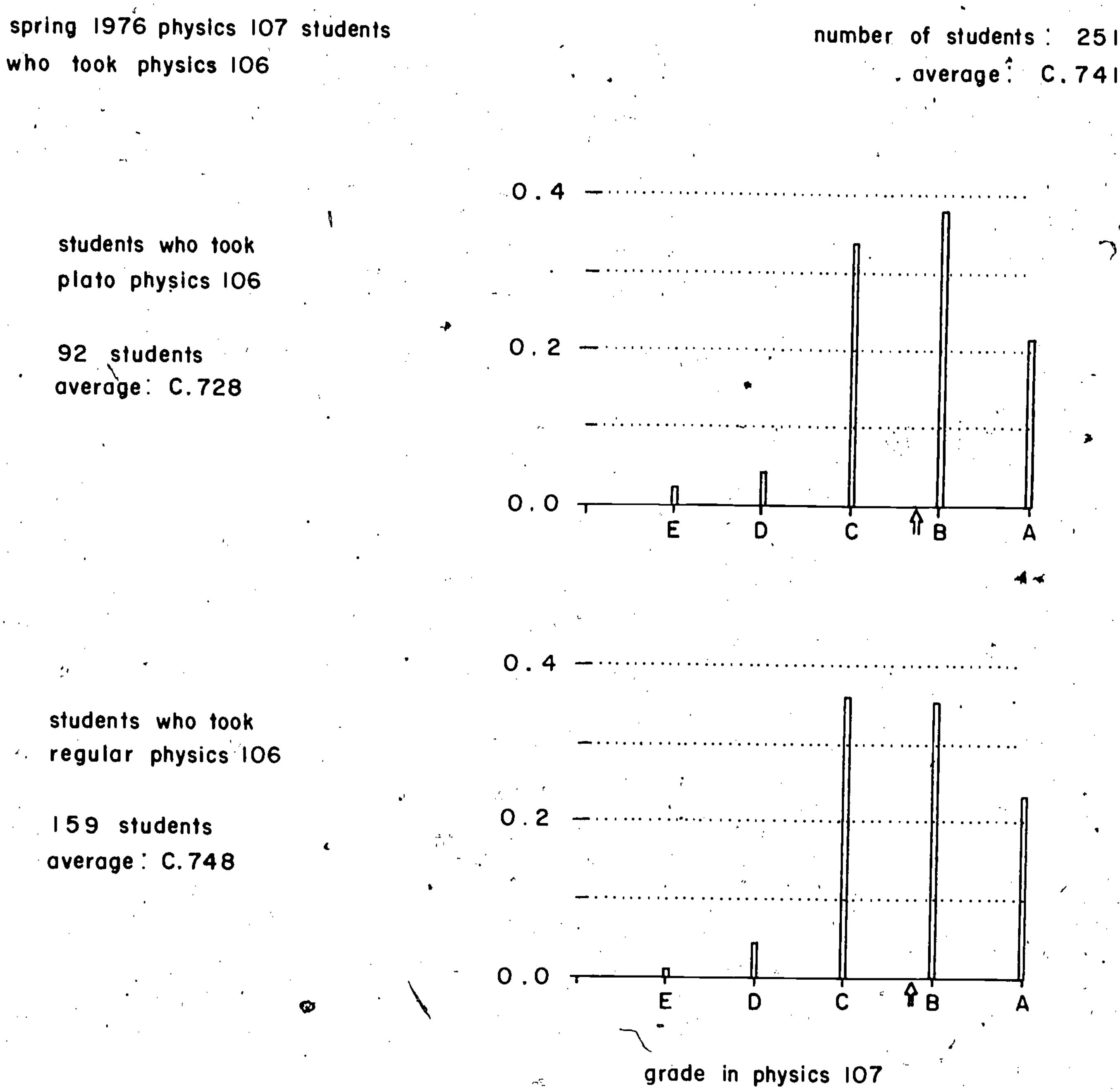

Fig. 7.3. Letter grades in Physics 107 for students who took PLATO and non-PLATO Physics 106.

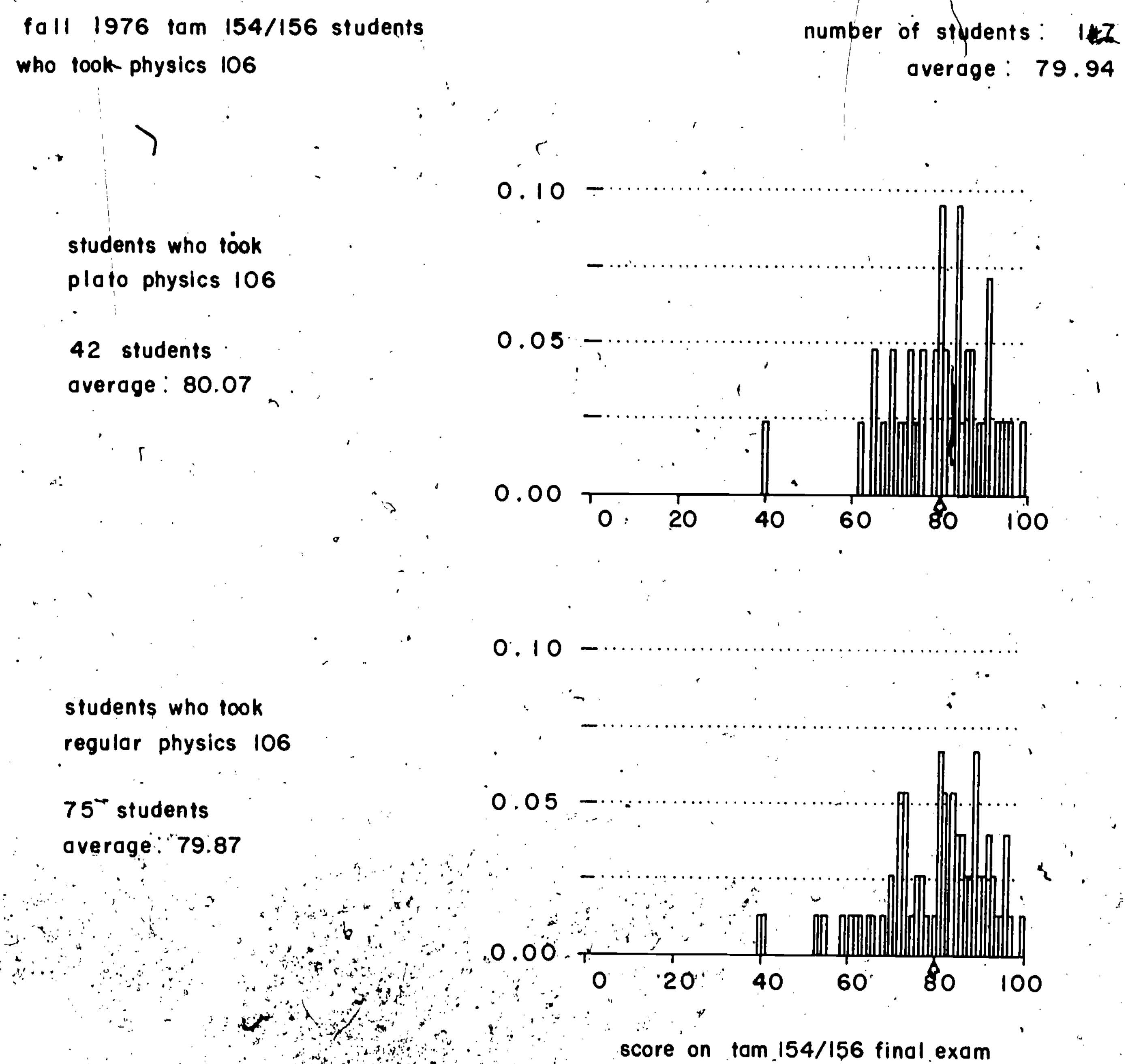

Fig. 7.4. Final exam scores in Theoretical and Applied Mechanics 154/156 for students who took PLATO and non-PLATO Physics 106.

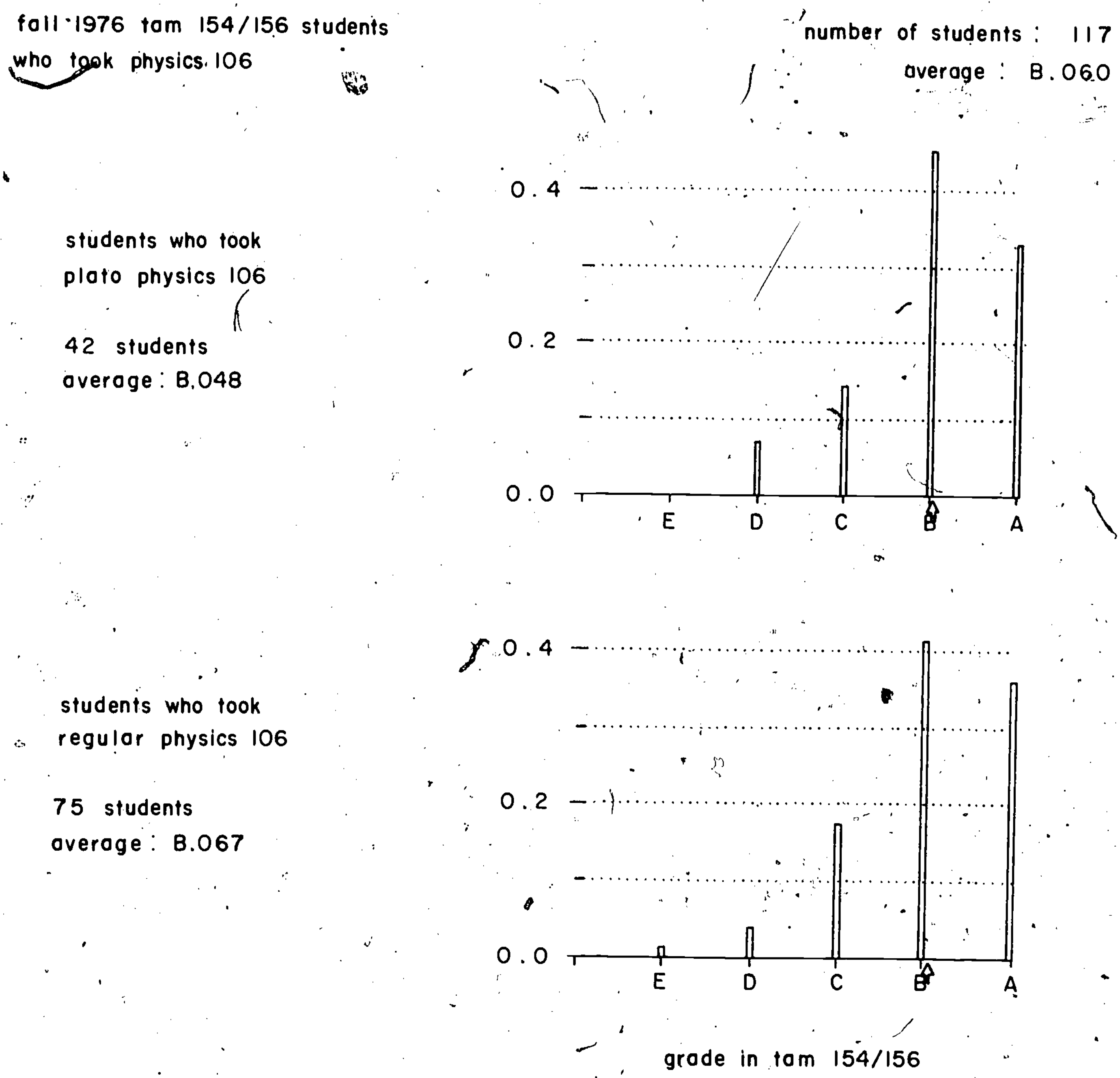

Fig. 7.5. Letter grades in Theoretical and Applied Mechanics 154/156 for students who took PLATO and non-PLATO Physics 106.

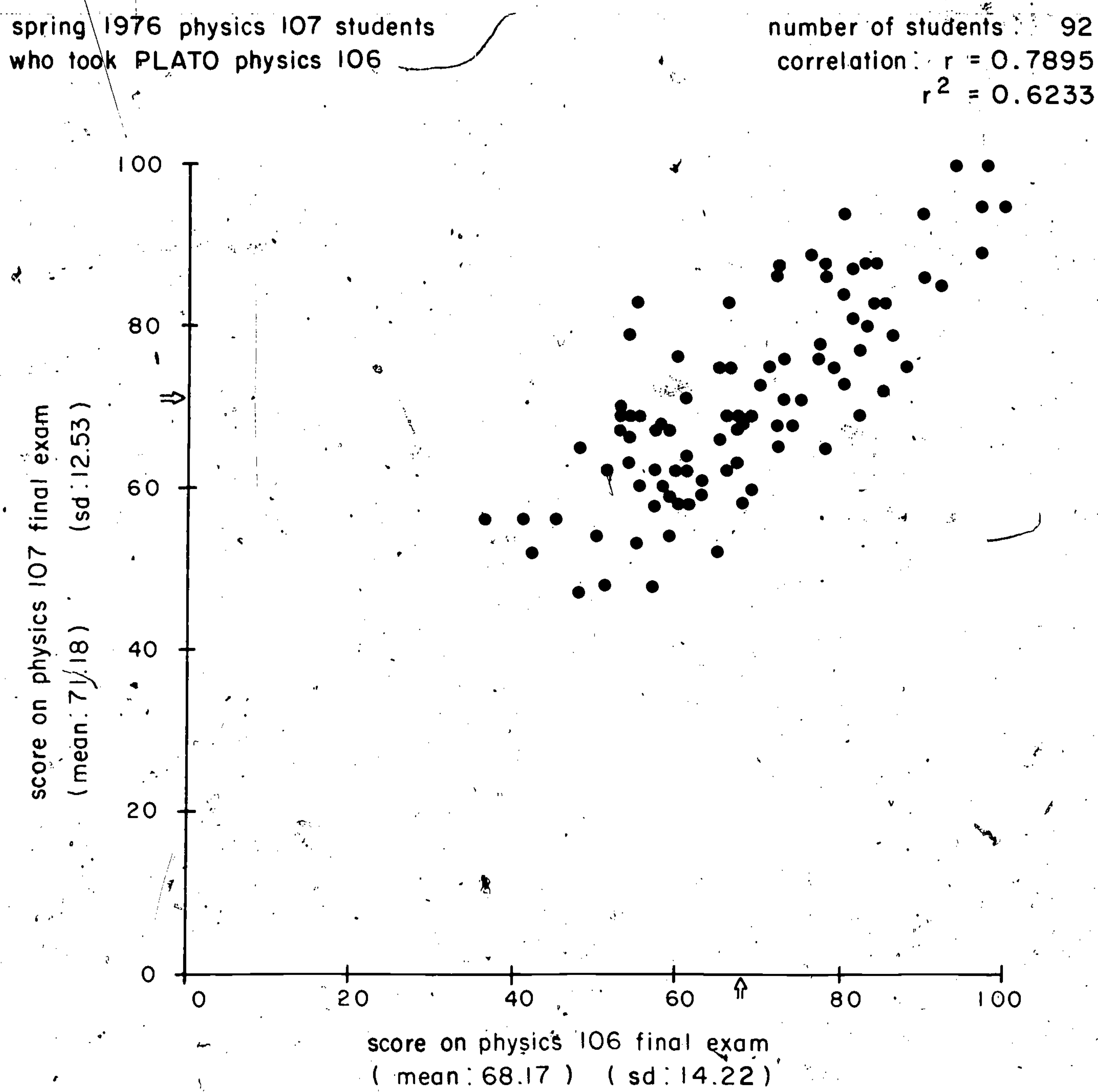

Fig. 7.6. Correlation of final exam scores in Physics 107 versus those in Physics 106, for students who took PLATO Physics 106.

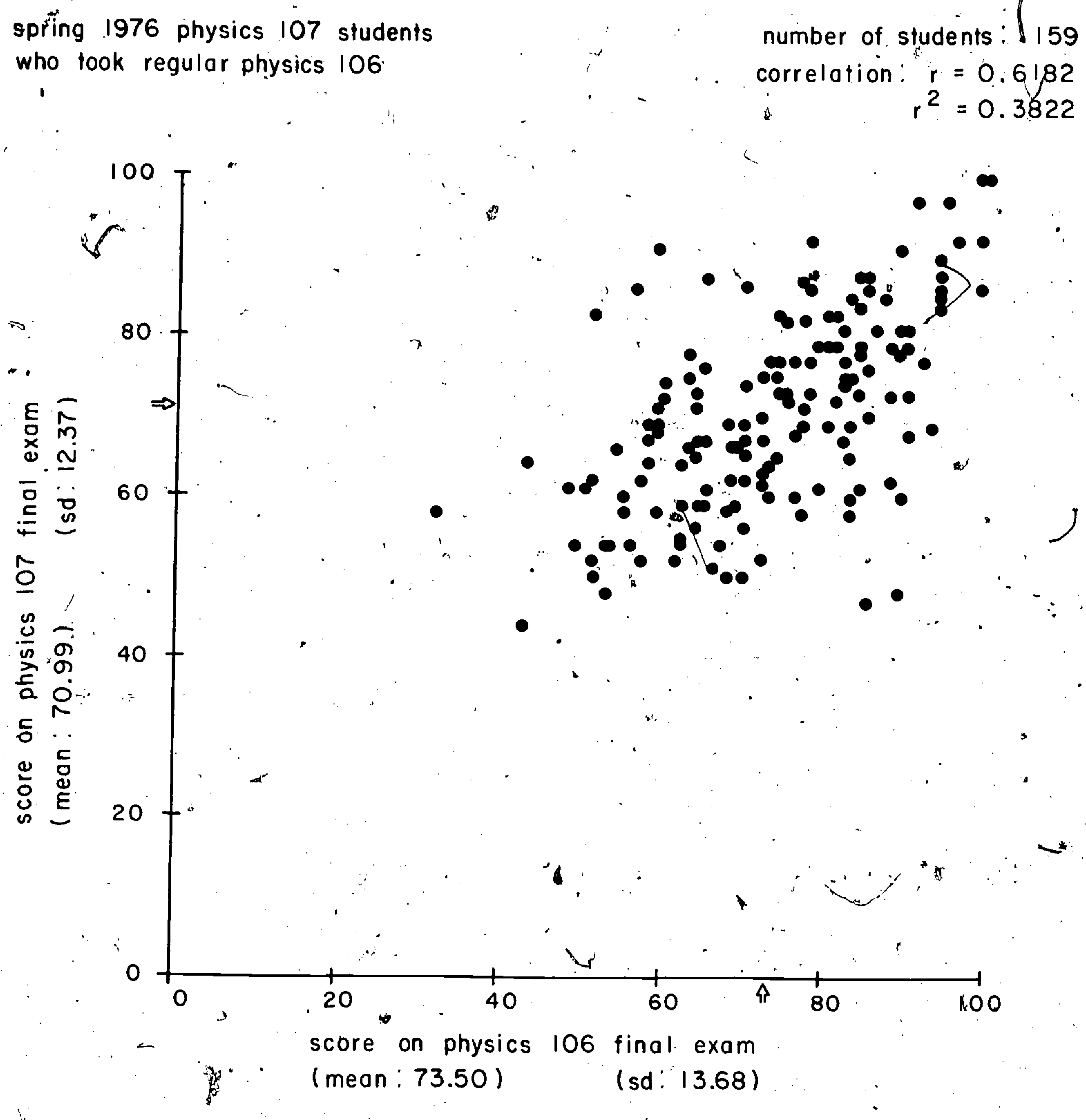

Fig. 7.7 Correlation of final exam scores in Physics 107 versus those in Physics 106, for students who took non-PLATO Physics 106.

instruction in Urbana is the necessity of being very careful in order not to exceed the amount of active lesson space available. At present, PLATO allots to Physics only enough active lesson space to permit ten or fifteen different lessons to be in use simultaneously by the up to thirty students in the physics PLATO classroom. This means that it is necessary to exclude most non-scheduled use of the terminals during most daylight hours in order to insure that a great enough variety of lessons will be available to those students enrolled in regular PLATO physics couses. These problems are recognized, and attempts are being made to increase the amount of active lesson space.

7.11 PLATO FEATURES PARTICULARLY USEFUL IN PHYSICS TEACHING

The fine graphical display and calculational features of PLATO play a fundamental role in all PLATO physics lessons. These features make it possible to make graphs and animated cartoons easily, which adds a great deal to the attractiveness of what the student sees. Animations are particularly useful for showing dynamic phenomena, as opposed to the static figures of a textbook.

Another basic PLATO feature which is used heavily in most physics lessons is the ability easily to analyze student responses of a numerical or algebraic nature. The handling of physical units at the dimensional level is also important.

The PLATO system's "module router" has provided the physics department with a very convenient mechanism for sequencing students through the appropriate lessons and for obtaining reports on student progress in the form of which lessons have been completed and what scores have been obtained on the homework exercises.

7.12 FUTURE DEVELOPMENT

Enough experience has been gained to encourage continued development. Some of this development will take place in the direction of refining and restructuring existing materials and the way in which these materials are used in courses. It has been suggested that the classical mechanics course might benefit a great deal from building in systematic review materials, something which has not been done so far. Students do go through lessons again for review purposes, but they may need a different kind of review mechanism, including short-answer quizzes every week or two. Another area likely to be further explored is the integration of PLATO with laboratory exercises. There already exist many PLATO simulated lab experiments, but more experience is needed in how best to exploit them. In the long run, given much more development, it might be possible to run more "tracks" of the courses. It should be easier to route students through differing versions of a PLATO course than can be conveniently done in a conventional course. It is likely that some teaching of numerical methods will be added to the courses, with students writing computational programs on PLATO as well as studying instructional lessons. An important development is the growing number of physics departments which have access to PLATO systems. It can be expected that this growth will lead to development of lessons in areas presently not covered and to the appearance of better lessons on topics presently covered.

7.13 PLATO PHYSICS MATERIALS SEPTEMBER 1976

The following lessons are in use in physics classes at the University of Illinois, Urbana, and at other PLATO sites around the country, including the University of Illinois at Chicago Circle, Carnegie-Mellon University, the University of Arizona, Valparaiso University, and the City Colleges of Chicago.

The average "completion" time for each lesson is given. This is the amount of time spent in reaching some criterion set by the author of the lesson. In the case of lessons which end with a mastery quiz, the completion time includes the time spent in the lesson up to the point where the quiz has been passed. The student does not have to complete a lesson in one sitting, because his personal record allows him to restart in the middle of the lesson. If a student reviews a lesson after completing it, the additional study time does not count in calculating the completion time.

7.13.1 Classical Mechanics

Introduction to PLATO (25 min)
Dennis Kane, UI Physics
Explains to students how to use PLATO in science courses. Treats keyboard and notation conventions common to PLATO science lessons, including how to erase and edit responses, how to use calculator mode, etc.

Introduction to Vectors (50 min)
Bruce Sherwood, UI Physics
Student moves a boy and a girl around on the screen, forming vector displacements, with questions about length and components. A brief review of trig precedes discussion of angle aspects of vectors.

One-dimensional Kinematics I (40 min)
Bruce Sherwood, UI Physics
Basic concepts of position, velocity, acceleration, and time

based on familiar aspects of automobile travel. Includes reading graphs. Applications. Mastery quiz.

One-dimensional Kinematics II (90 min)
Bruce Sherwood, UI Physics
Simple numerical integration (with graphs) leads up to student derivation of the equation $x_f = x_i + v_i t + at^2/2$. Applications. Mastery quiz.

Graphical Kinematics I (120 min)
Ed McNeil, UI Chicago Circle Physics
Connection between slope and derivative: graphical differentiation. Student makes inputs by means of a graphics cursor.

Graphical Kinematics II (60 min)
Ed McNeil, UI Chicago Circle Physics
Connection between area and integral. Graphical integration. Student makes inputs by means of a graphics cursor.

Two-dimensional Kinematics (170 min)
Bruce Sherwood, UI Physics
Introduces and tests basic concepts of vector displacement, velocity, average velocity, and acceleration. Various applications deal with kicking a football. Also treats circular motion, including a derivation of the radial acceleration v^2/r. Applications include satellite motion. Mastery quiz.

Introduction to Relative Motion (15 min)
Carol Bennett, UI Physics
Derivation of the basic formula for Galilean transformation of velocity between moving coordinate frames.

Conservation of Momentum (45 min)

Bruce Sherwood, UI Physics (revised by Dennis Kane)
Animated displays shows elastic and inelastic collisions. Momentum conservation is found by explicit calculations from the simulated experiments. Applications. Mastery quiz.

Forces and Free-body Diagrams (70 min)
Carol bennett, UI Physics
Introduces typical forces, including tension in a string and friction between surfaces. Treats the concept of a free body and has the student isolate and analyze various kinds of subsystems for the forces.

Free-body Diagrams (without rotation) (80 min)
Bruce Sherwood, UI Physics (revised by Craig Burson)
Drills the student on a systematic approach to solving dynamics problems. Treats one- and two-body systems. Student picks a subsystem, identifies the forces, writes the equations of motion, writes the geometrical constraint equations, and solves the algebra. Mastery quiz.

Work and Kinetic Energy (70 min)
Dennis Kane, UI Physics
Relation between work and kinetic energy, with applications involving constant forces. Includes treatment of dot product.

Work Done by Position-dependent Forces (20 min)
Dennis Kane, UI Physics
Student divides a force-distance curve in successively smaller steps to approach an integral. Applications include work done by a spring.

The Work-Energy Equation (70 min)
Bruce Sherwood, UI Physics
Treats the general work-energy equation, including thermal and other internal energies (essentially the first law of thermodynamics, but in a mechanics setting). Includes a detailed treatment of work done by friction. Final section deals with the effect of the choice of subsystem on the form of the work-energy equation.

Moment of Inertia and Rotational Kinetic Energy (20 min)
Dennis Kane, UI Physics
Calculation of I and KE for various rotating systems.

Torque and Angular Momentum (60 min)
Bruce Sherwood, UI Physics
Drills on direction and magnitude of torques applied by a wrench (treatment is mainly two-dimensional). Angular momentum is calculated for a spinning and translating dumbbell. Example of angular momentum conservation.

Free-body Diagrams (with rotation) (70 min)
Bruce Sherwood, UI Physics (revised by Craig Burson)
Drills the student on a systematic approach to solving dynamics problems. Treats one- and two-body systems. Student picks a subsystem, identifies the forces, writes the equations of motion, writes the geometrical constraint include the torque equation. Mastery quiz.

Oscillations: Simple Harmonic Motion (110 min)
Bruce Sherwood, UI Physics
Basic concepts of amplitude, period, and frequency are

introduced in connection with a calculable anharmonic oscillator (two inclines facing each other). Spring-mass system treated by analogy with circular motion, and by optional calculus treatment. Experimental simulations. Applications include pendulums. Mastery quiz.

Homework Sets for Classical Mechanics
Problems by James Smith, UI Physics, programming by Dennis Kane, assisted by Bruce Sherwood.
Fourteen sets, each containing eight problems, which span the introductory science-oriented classical mechanics course. Four sets are available in two different versions, depending on whether the course treats momentum before energy or vice versa. Many problems are illustrated by line drawings or animations. Numerical parameters in problems are generated on the basis of the letters in the student's name. Each set outputs a score on a scale of 0-100. Student responses are checked for numerical and dimensional accuracy. Errors in units or in typing (such as unbalanced parantheses) are explained to the student, but wrong answers are simply reported as incorrect without telling the correct answer. The level of the problems is moderate to difficult.

Phizquiz: A review of Classical Mechanics (50 min)
Brad Peterson, UI Physics, with James Smith (revised by Dennis Kane)
Eight problems from major areas of classical mechanics. Basic situation is described--then student must "buy" specific information (masses, velocities, etc.). Student is charged for irrelevant information, so that care is required to solve the problem at minimum cost.

20 Multiple-Choice Mechanics Questions (25 min)
Tom Lemberger, UI Physics
Review questions on all areas of classical mechanics.

7.13.2 Relativity

Introduction to Special Relativity (20 min)
Donald Shirer, Valparaiso University
Introduction to a series of lessons on special relativity. Outlines approach, conventions used, help available. Discusses measurements made by co-moving observers.

High-Speed Physics (50 min)
Donald Shirer, Valparaiso University
Describes two experiments which show that modifications must be made to classical formulas for momentum and energy at very high velocities. Discusses implications of these formulas and their prediction of an ultimate "speed limit".

Mass and Energy (50 min)
Donald Shirer, Valparaiso University
Discusses differences between kinetic, potential, total and rest energy, and shows that the Einstein mass-energy formula is compatible with the p,E laws found earlier.

7.13.3 Drills

Drill on Vector Addition and Subtraction (45 min)
Dennis Kane, UI Physics
Mixed drills, including the calculation of magnitudes and angles.

Drill on Momentum in Collisions (7 min)
Dennis Kane, UI Physics
Drill on analyzing collisions of two particles.

Center-of-mass Drill (5 min)
Dennis Kane, UI Physics
Two to four particles are shown on a grid, and the student must calculate and point to the center-of-mass.

Relative Motion: Boat on a River (15 min)
Carol Bennett, UI Physics
Student tries to steer a boat to different points on the opposite bank of a flowing river. Animation shows the boat as it moves across the river.

Combining Experimental Errors (20 min)
Carol Bennett, UI Physics
Combining of errors for addition, subtraction, multiplication, and division of experimental quantities.

GRAFIT Programming Facility
Bruce Sherwood, UI Physics
A simple programming language with inherent graphical output, designed to assist science students to compute and graph results for small calculations.

Physics Games
Carol Bennett, UI Physics

Mechanics-oriented games, including projectile motion, determining target shapes from collision information, landing on the moon, and interplanetary travel.

The Vector Olympics
Bruce Sherwood, UI Physics
Three vector-associated games: estimating lengths of vectors in centimeters, algebraic form of components of a vector in randomly-chosen coordinate frames, and centimeter lengths of components in such frames. Touch panel required.

Torque Game
Carol Bennett, UI Physics
Three exercises of increasing difficulty involving balancing masses on a pivoted rod. Touch panel optional.

Workout
David Sutton, UI Physics (assisted by Bruce Sherwood).
Games related to work, including dot product and estimating areas under force-distance curves. Touch panel required.

Game Balancing Three Forces (15 min)
Carol Bennett, UI Physics
Student must apply three forces to an object in such a way that the object does not accelerate.

Interterminal Problem-solving Contest
Dennis Kane, UI Physics (assisted by James Smith)
Students at different terminals can challenge each other to see who can solve a physics problem in the shortest time.

Interterminal Game of Physics Formulas
Charles Guerra, UI Medical Center (assisted by Howard Balfour)
Students at different terminals can challenge each other to produce specific physics formulas or to convert between different systems of units.

7.13.4 Modern Physics

Waves: travelling waves and the wave equation
Carol Bennett, UI Physics
Aided exercises with components of a travelling wave and differentiation to test the wave equation and find v.

Waves: vibrating string experiment
Carol Bennett, UI Physics
Description of a vibrating string plus simulation of an

experiment in finding the wavelength of standing waves.

Waves: resonances in pipes with an experiment
Carol Bennett, UI Physics
Description and questions on standing waves in pipes with a 3-part experiment with an open pipe.

Waves: Doppler effect
Carol Bennett, UI Physics
Dennis Kane, UI Physics
Guided derivation of Doppler shift(cb); exercises(dk)

E-M radiation: polarizers
Carol Bennett, UI Physics
Summary on polarizers; template with help for working problems on 1 to 3 polarizers.

E-M radiation: slit interference and diffraction
Carol Bennett, UI Physics
Simulation of intensity patterns for varied slit width, separation, and number.

E-M radiation: phase (vector) diagrams with quiz
Carol Bennett, UI Physics
Construction of interference patterns from addition of electric field vectors; quiz on properties of patterns.

7.13.5 Geometric Optics

Snell's law
Carol Bennett, UI Physics
Two games involving a refracting surface

Thin lenses
Carol Bennett, UI Physics
Graphical exercises drawing the principal rays for a concave and a convex thin lens; calculate image position.

Plane mirrors
Carol Bennett, UI Physics
Graphical exercise locating the images for two perpendicular plane mirrors.

Spherical mirrors
Carol Bennett, UI Physics (assisted by Dennis Kane)
Numerical exercises (fill-in-the-table) for spherical mirrors, varying the unknown quantities.

Sign conventions in optics
Carol Bennett, UI Physics
Randomly generates a lens, mirror, or curved surface, draws the principal rays, and asks for the signs of the focal length, object and image positions.

Geom. optics: homework problems with help
Carol Bennett, UI Physics

7.13.6 Particles and Waves

Heisenberg Uncertainty Principle
Carol Bennett, UI Physics
Discusses k and x for a particular wavefunction form; a few of these are measured for a varying parameter in the wavefunction, tabulated with estimated error, and compared with the analytical result the student derives in the lesson.

Photoelectric effect
Carol Bennett, UI Physics (assisted by G. Weast, T. Little)
Exercises with simulations involving the photoelectric effect; finding kinetic energy from retarding potential; finding work function of a metal from simulated current measurements.

7.13.7 Elementary Quantum Mechanics

Infinite square-well potential
Carol Bennett, UI Physics
Properties of infinite square-well wavefunctions and energies.

Finite potential wells and barriers
Carol Bennett, UI Physics
Wavefunctions are plotted for arbitrary finite potential well and barriers; analytic forms are shown with the numberical coefficients.

Finite potential-well wavefunctions
Carol Bennett, UI Physics
Guided exercises in finding bound states for 3 finite potential wells.

Quantum mechanics
Carol Bennett, UI Physics
Review problems.

Atomic quantum numbers
Carol Bennett, UI Physics
Timed exercise in identifying the n,l,m atomic quantum numbers for a given system.

Molecular vib/rot spectra
Carol Bennett, UI Physics
Vibrational and rotational energies and photon emissions in a diatomic molecule.

Nuclear decay
Carol Bennett, UI Physics
Simulation of neclear decay and exercises to find half-life from a plot of the decaying particles including fitting the data to an exponential decay function.

General: review questions from past exams, multiple choice
Carol Bennett, UI Physics

7.13.8 Thermal Physics

Thermal Equilibrium (30 min)
Donald shirer, Valparaiso University
Open-ended simulation of an experiment in which molecules exchange energy randomly and go from ordered to disordered (equilibrium) state similar to Boltzmann Distribution.

7.13.9 Elementary Electric

Circuits
Carol Bennett, UI Physics
Plots of current vs. time in rl,rc,rlc circuits with exercises on what should be expected.

Game with charges
Carol Bennett, UI Physics
Find 1 to 4 randomly located point charges by measuring the electric field; introduction on fields and forces.

7.13.10 Intermediate Optics

Ray tracing
David Sutton, UI Physics

Ray tracing thru a single spherical refracting surface; spherical aberration.

Optical path length
David Sutton, UI Physics
OPL vs displacement of ray from the optic axis at spherical surfaces.

Fermat's principle
David Sutton, UI Physics
Experimental minimization of the OPL between two points separated by two plane surfaces (3 indices); checked by ray tracing.

7.13.11 Intermediate Quantum Mechanics

Wavefunctions for 1-D potentials
Carol Bennett, UI Physics
Plot wavefunctions for any chosen potential V(x)

Wavefunctions for radially symmetric potentials
Carol Bennett, UI Physics
Plots wavefunctions for arbitrary potentials V(r); calculates phase shifts.

Addition of angular momentum
Carol Bennett, UI Physics
Exercises illustrating the addition of angular momentum; brief introduction to Dirac notation.

Matrix algebra
Carol Bennett, UI Physics
Review of matrices as applied to q.m.; simple exercises.

Helium atom
Carol Bennett, UI Physics
Analytical calculation of electron single-particle pseudo potential; introduction to self-consistent calculation.

Helium atom
Carol Bennett, UI Physics
Self-consistent calculation of electron wave function; charge in nucleus and angular momentum quantum number may be changed.

7.13.12 Service Routines

Calculator/function plotter
Carol Bennett, UI Physics
Elaborate calculator and x-y function plotter with user-defined functions A-Z and variables a-z.

Mini-calculator
Carol Bennett, UI Physics
Small calculator without user-defined functions; includes real or complex numbers, random numbers, array operations.

Root finder
Carol Bennett, UI Physics
Finds x for arbitrary f(x)=0 step-wise search and interpolation.

Least squares
Carol Bennett, UI Physics
Linear and quadratic fit to data points without weighting.

Numerical integration
Carol Bennett, UI Physics
Introduction with exercises.

Numerical integration
Carol Bennett, UI Physics
4th-order Runge Kutta for 1 to 4 equations.

Simultaneous linear equations
Carol Bennett, UI Physics
Solves a set of simultaneous linear algebraic equations.

Eigenvalues and eigenvectors
Carol Bennett, UI Physics
Finds the eigenvalues and eigenvectors for real symmetric matrices.

8. UNIVERSITY CHEMISTRY

8.1 SUMMARY

Support from this NSF grant provided funds to purchase 30 PLATO IV terminals and the necessary communication equipment to establish a PLATO classroom within the Department of Chemistry at the University of Illinois. Lesson material has been developed to use this facility in the teaching of general and organic chemistry. At the present time approximately 1000 students use the terminals from 1 to 2 hours per week to study assigned lesson material. In general student acceptance of instruction on PLATO has been very good. In one questionnaire 96% of the students in an organic chemistry course said that PLATO helped them learn the material.

8.2 CHEMISTRY AUTHORS

The authors of the lesson materials have all been members of the Department of Chemistry. Dr. Ghesquiere was involved with PLATO III and the initial phases of the PLATO IV programming. Ms. Moore is just beginning work on lesson material and Dr. Myers wrote a set of lessons on carbohydrate chemistry during a brief post-doctoral program. Dr. Ruth Chabay has been instrumental in the development of the programs for the teaching of general chemistry and Dr. Smith has done much of the work on the organic chemistry material.

A summary and brief description of the programs which have been developed is given in section 8.8.

8.3 DEVELOPMENT OF INSTRUCTIONAL MATERIAL

Our research into the use of computers to help students learn chemistry was initiated on PLATO III in 1968. These efforts were directed towards ways to provide individualized instruction which could be used by the students in large lecture courses who have difficulty obtaining help specific to their needs.

Each program has been written by one individual who serves as the instructional designer and programmer. This approach does not impose other individuals between the experience and creativity of the teacher and the final instructional lesson.

The programs which were developed on PLATO III and tested with small groups of students were transferred to PLATO IV. The completions of the chemistry classroom coupled with the steady growth of new lesson material on PLATO IV is reflected in the use of chemistry lesson material which is summarized in Table 8.1. At the present time, approximately 1000 students at the University of Illinois use PLATO to study chemistry for 1 to 2 hours per week. This level of use essentially saturates the facility and expansion in the use of PLATO in chemistry requires the acquisition of additional terminals.

Table 8.1
Use of Chemistry Lessons

Academic Year	Hours of Use
1973-74	4,400
1974-75	30,960
1975-76	51,500

In addition to the use of the chemistry programs at the University of Illinois, about 1/4 of the total usage of the lessons occurs at other colleges and Universities associated with the UI PLATO system.

The spread of hours of use of the system by students in a typical course is shown in Fig. 8.1. The number of lessons completed by these students is illustrated in Fig. 8.2. It is interesting to note that only 30 lessons were assigned so most students did more than the required amount of work. The wider variation in the time that students work than in the number of lessons they completed, of course, reflects the difference in the rate at which students complete instructional material.

The lesson material is written in a variety of pedagogical styles and includes tutorial dialogs, animations, simulated experiments, open-ended multistep organic synthesis, drills, and chemical games. In general, the lessons are used to supplement and extend the lecture component of the course. Usually each lesson has an internal index so students may select and review particular sections of a lesson or skip others which have already been mastered. "Credit" for completing a lesson is usually based on satisfactory completion of a review problem set.

An important component in the design of the instructional material has been the incorporation of simulated experiments which allow students to repeat classic experiments and to gain experience in the design of experiments and the interpretation of data. For example, one lesson allows organic chemistry students to study the effect of the concentration of alkoxide on the rate of reaction of n-butyl bromide and t-butyl bromide in ethanol through computer simulations as an aid to understanding unimolecular and

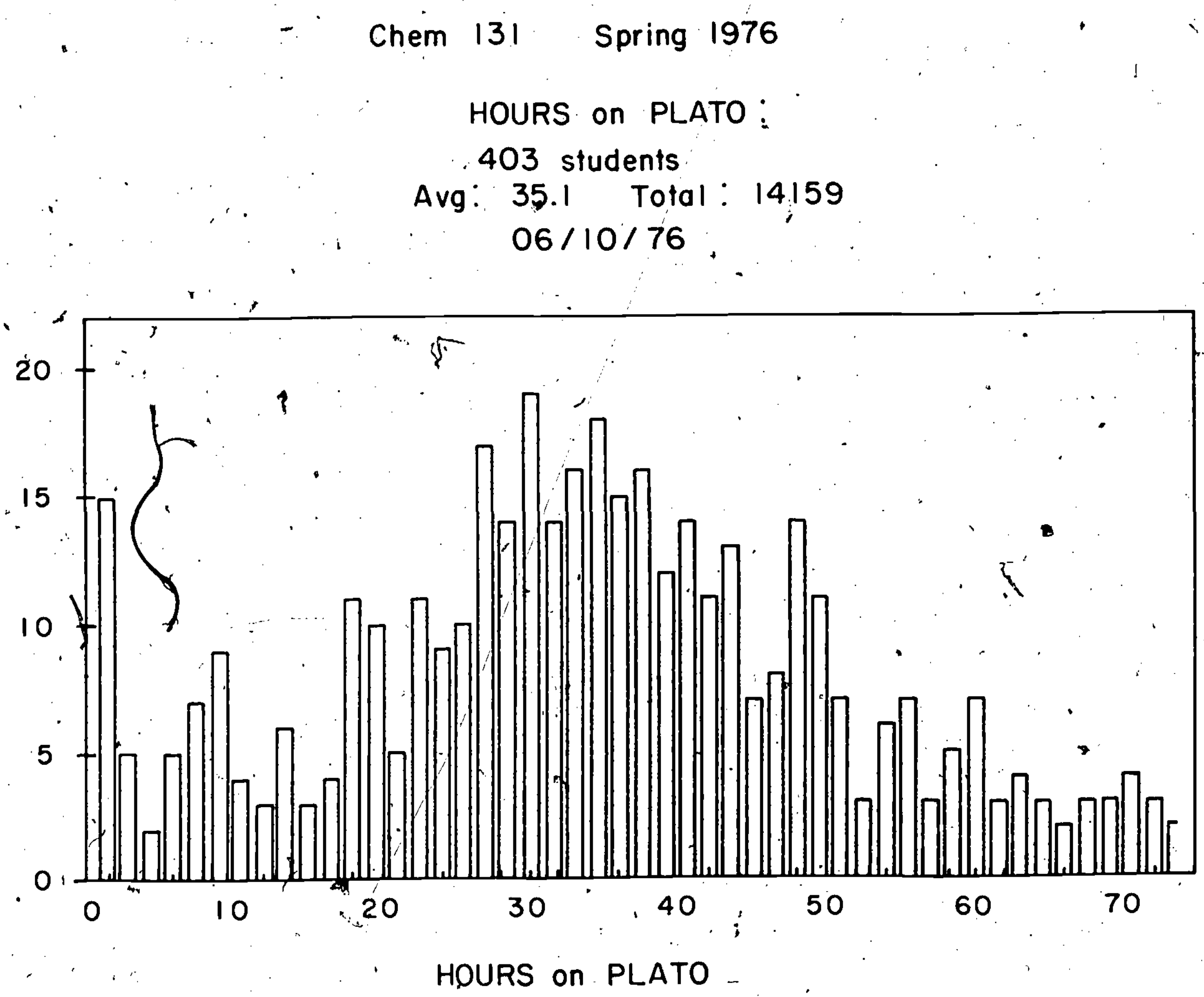

Fig. 8.1 Hours of PLATO use by 403 students in typical chemistry course.

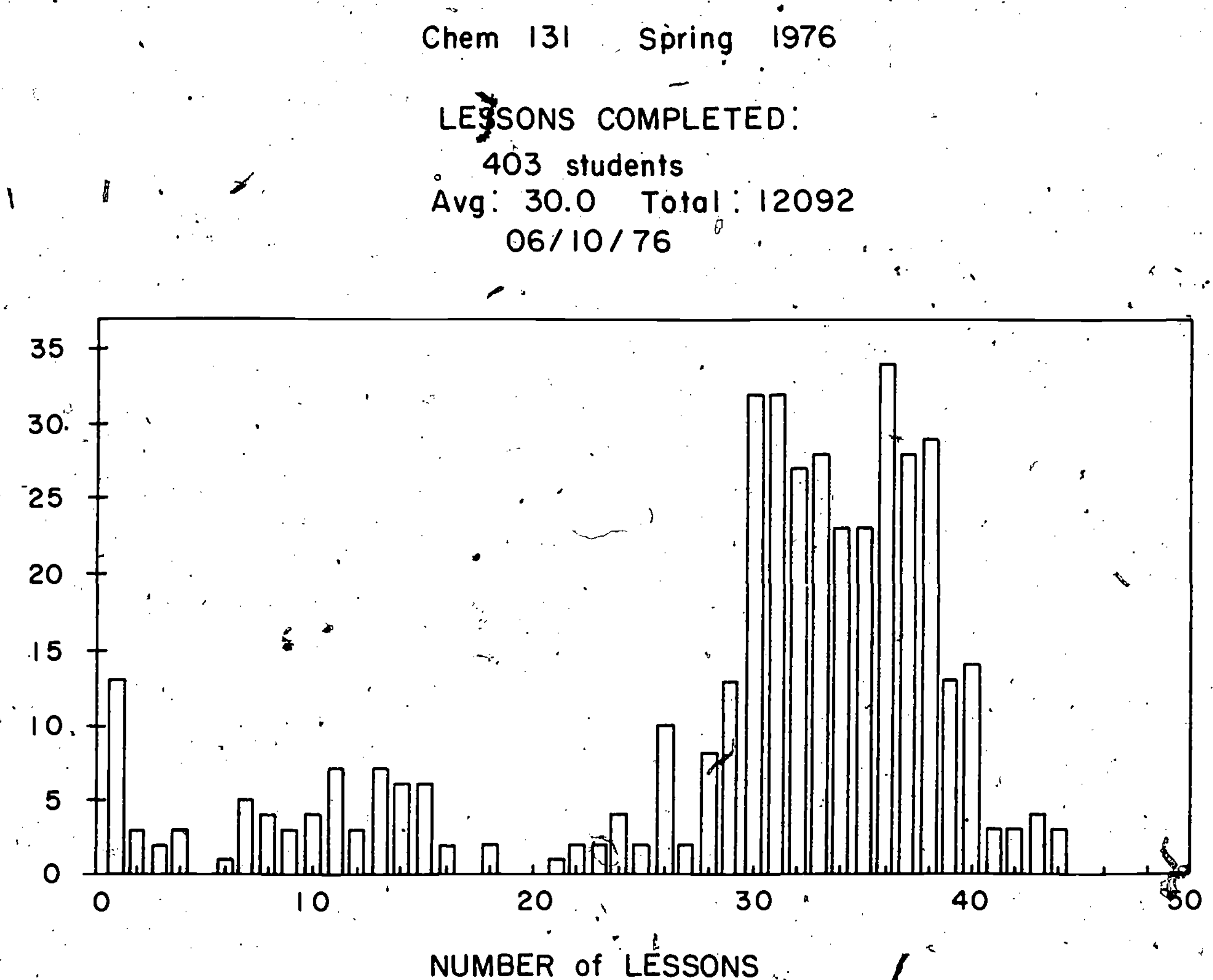

Fig. 8.2 Numbers of lessons completed by 403 students in typical chemistry course.

bimolecular substitution and elimination reactions. Animations then graphically illustrate the sterochemistry of these processes to further enhance the students understanding of these basic reaction mechanisms.

8.4 DESCRIPTION OF COURSES USING PLATO

General Chemistry: The general chemistry course for students with no prior chemistry has an enrollment of 400 to 500 students per semester. The one lecture per week, a quiz section and a laboratory are now supplemented by 35 PLATO lessons. On the average, the students in this course spend 1.2 hours per week doing the assigned PLATO lessons. They come at anytime they like, although an automatic site management scheme gives them priority on the use of the terminals between 8 am and noon on week days.

The 35 lessons in this course cover the basic theoretical principles and give students individual help working problems on other topics including the metric system, scientific notation, nomenclature, basic atomic structure, ionic and covalent bonding, chemical formulas, balancing equations, stoichimometry, ideal gas laws, and chemical equilibrium.

Organic Chemistry: Two beginning organic chemistry courses at the University of Illinois now use PLATO as a required part of the instructional program. The course for non-majors has 400 to 500 students per semester while the course for chemistry majors has 80 to 200 students per semester. Each of these courses meets three times per week plus required work on PLATO. The same basic set of PLATO lessons is used in both courses with some additional programs required for the chemistry majors. At the present time between 30 and 35 lessons are used each semester.

The programs cover each major topic in the course: nomenclature, optical activity, conformational analysis, alkenes, arenes, alcohols, aldehydes, ketones, amines, carboxylic acids, NMR, IR, and multistep aromatic and aliphatic synthesis. Students are given credit towards their final grade for completion of the programs which constitutes about 10% of the total course grade. On the average students spend about 2 hours per week working these programs.

In addition to the instructional lessons, the PLATO system serves as a communication link between the students and the instructor through the use of student notes. Additional services provided the student include an on-line gradebook which gives them detailed information on their class standing, answers to hour exams, reading and homework assignments. Part of the grade-book is illustrated in Fig. 8.3.

Just as with the general chemistry course, the organic chemistry students may work when ever they want, although the automatic class management system give them priority on the use of the terminals during the afternoon hours.

Qualitative Organic Analysis: In a senior level qualitative organic chemistry course students spend the first few laboratory periods reviewing the basic chemical and spectroscopic analysis techniques which are required for the identification of unknown compounds. Then they practice their deductive strategies by attempting to identify compounds through computer simulations of the laboratory. After solving about a dozen unknowns on the computer the students are then allowed to go to the laboratory and deal with real compounds.

Data on Lesson Performance: The extensive data collecting capability of

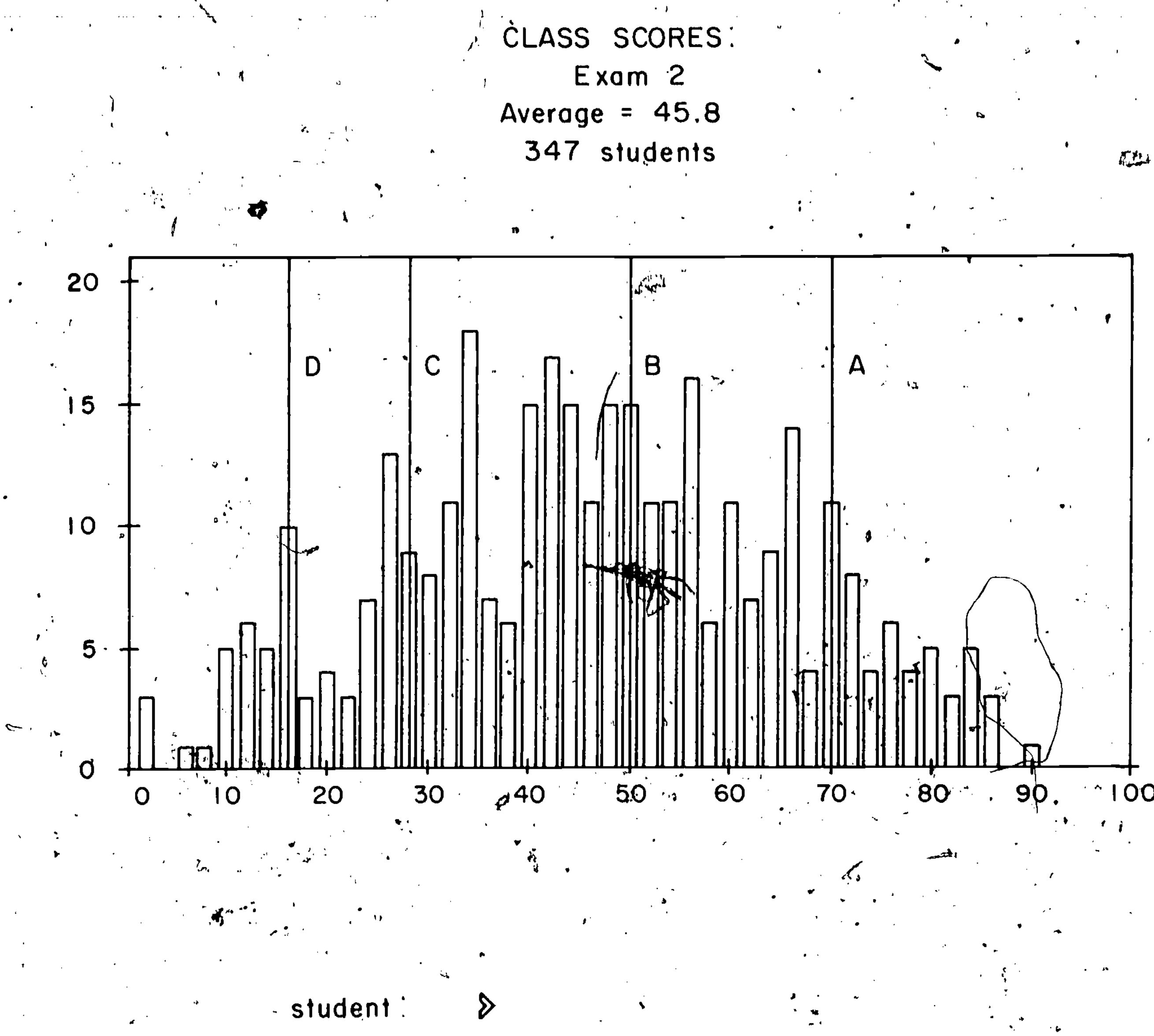

Fig. 8.3 Distribution of examination scores for 347 students in typical chemistry course.

the PLATO system has made it possible to gather data on the use of the lessons. For example, Fig. 8.4 shows a plot of the number of errors students made in working one section of a lesson. The error rate shown can be put into better context by looking at the % of the questions which students got right without help as shown in Fig. 8.5. It has been valuable to review plots of this type for new lessons to be sure that the problems are not too easy (high %ok) or too hard (low %ok). Where data of this type indicate that the lesson is not working correctly, the program is modified. The scatter in the plot of time vs. errors shown in Fig. 8.6 illustrates the diverse abilities and rates at which students work and serves to reinforce the desire to provide an instructional system such as PLATO which will adjust to students as individuals rather than trying to force them all to work and learn at the same rate.

8.5 STUDENT ACCEPTANCE

In general student acceptance of instruction presented on PLATO has very good. For example in a questionnaire, 96% of the students in an organic chemistry course said that PLATO helped them learn organic chemistry while 2% said it had no effect and another 2% felt that it hindered their learning. When asked how they would advise a friend, 57% said to take PLATO "if at all possible" and 27% voted for"fight tooth and nail to get into the PLATO section". Between 1 and 2% of the students did not think PLATO should be used. In addition 90% of the students indicated that the same number or more programs should be used in the course.

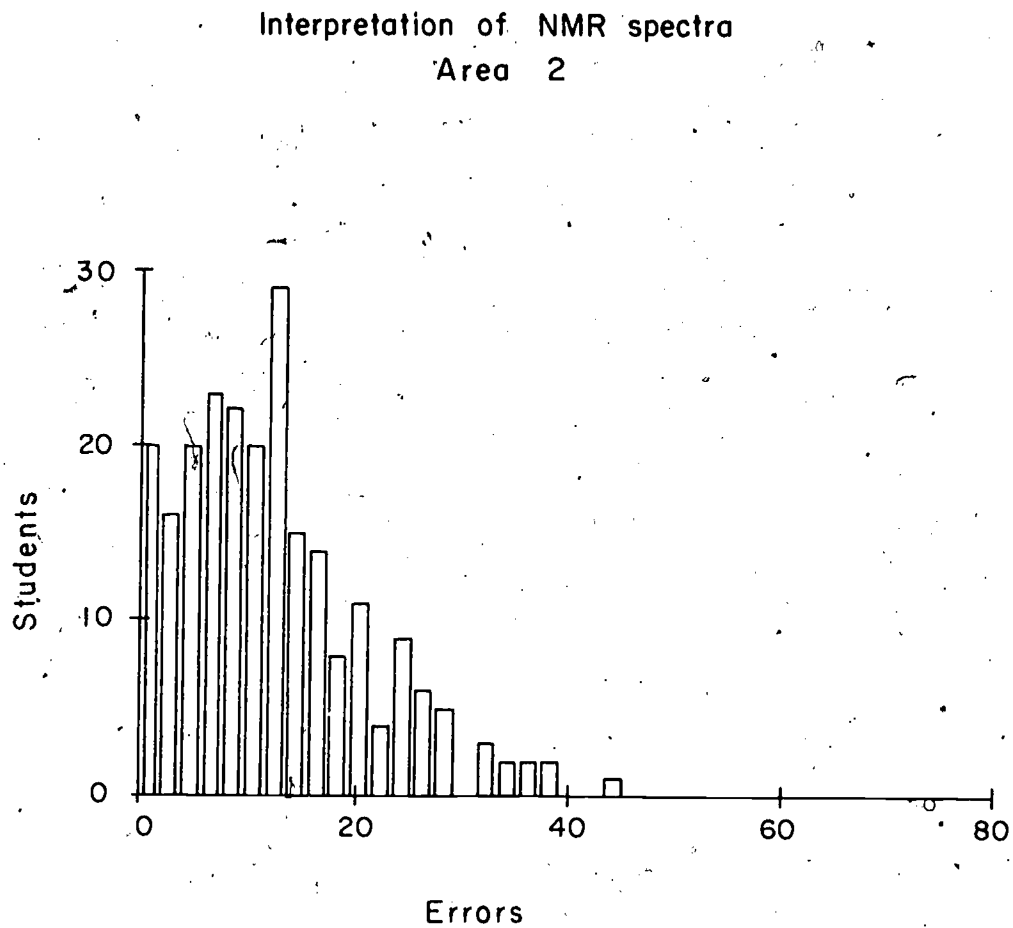

Fig. 8.4 Distribution of errors made by students in working one section of a chemistry lesson.

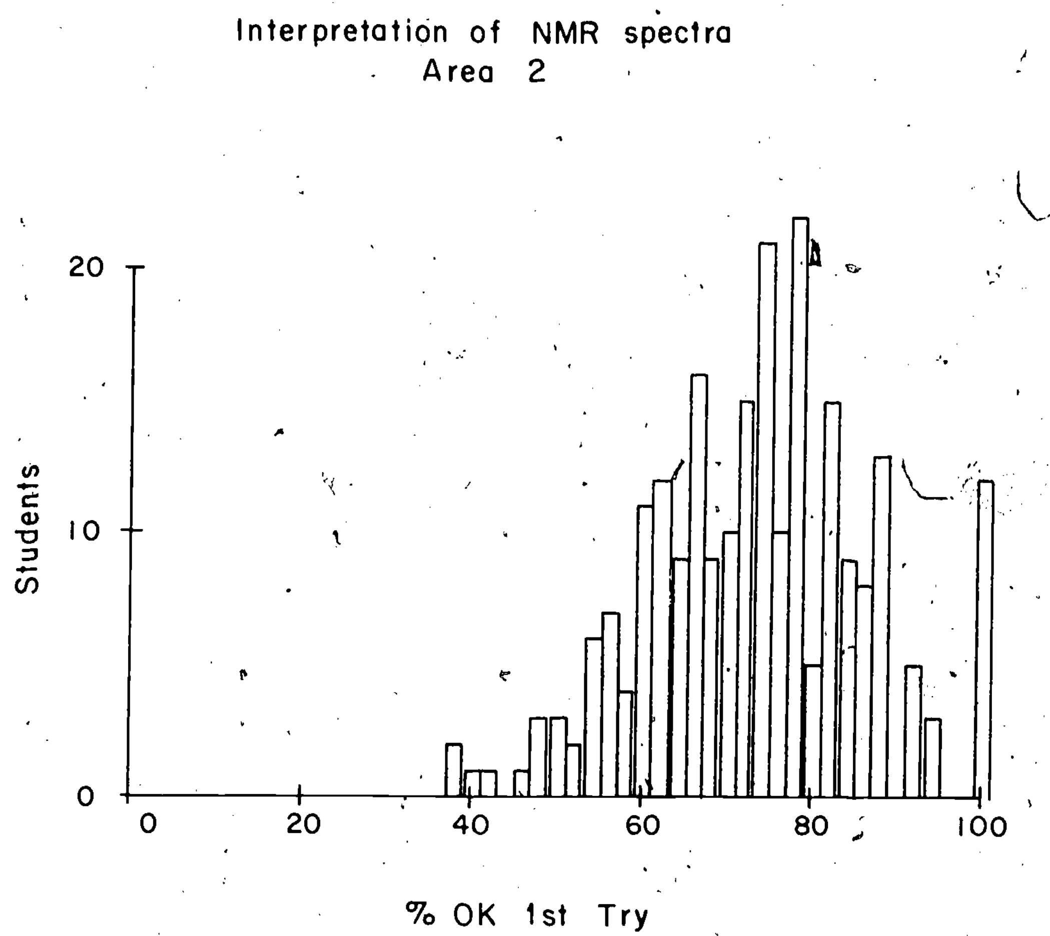

Fig. 8.5 Distribution among students of the number of questions answered correctly on first try for one session on a chemistry lesson.

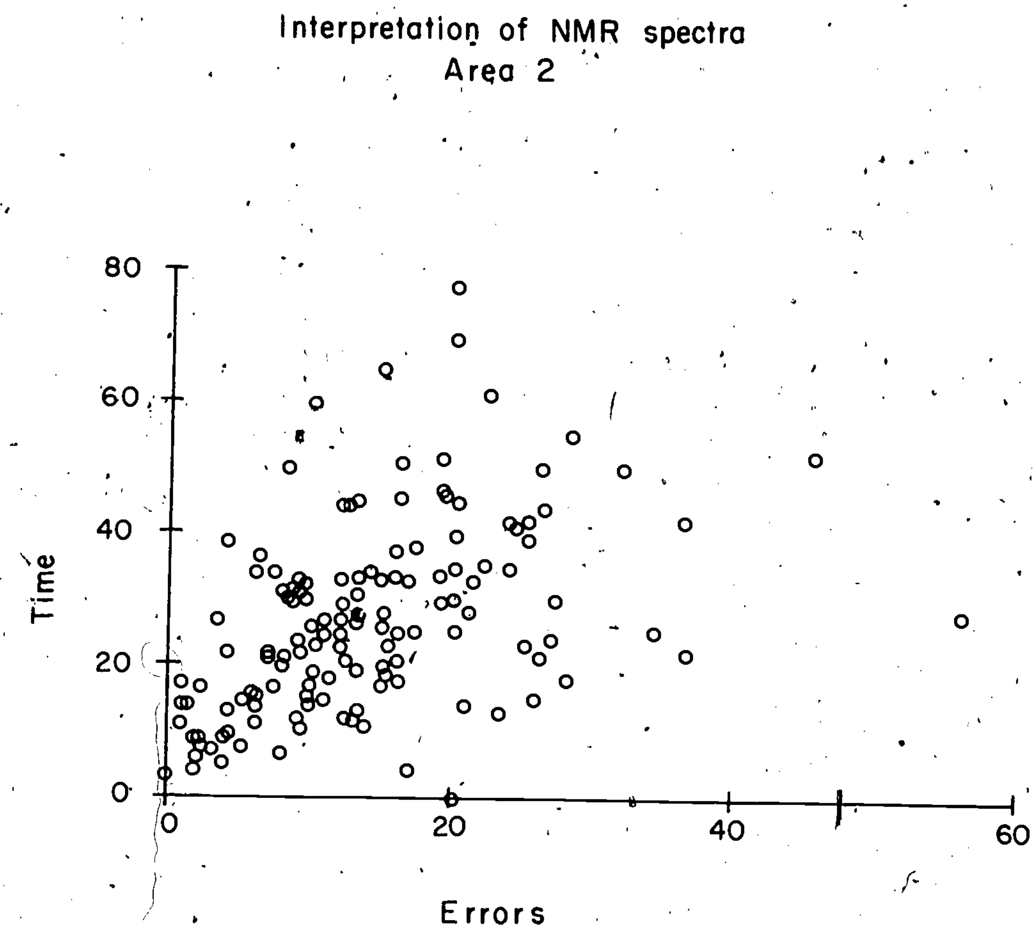

Fig. 8.6 Relations of time spent at PLATO terminal to number of errors made.

Student comments also serve as an indication to the acceptance of this type of instruction. Students have commented:

"PLATO is probably the most valuable tool for learning in this course. Learning is accomplished at one's own pace and, best of all, at a civilized hour (i.e., not at the crack of dawn). The lectures are too impersonal, making it both difficult to pay attention and worst of all, impossible to ask questions in"

"I feel that PLATO is and can easily continue to be a valuable instructional tool. PLATO has the capacity of providing the student with practice problems together with immediate results of his work. Thus I highly recommend the continued use of PLATO as a supplement to not only this but other courses."

"PLATO is a marvelous tool and I find 'learning with it' a great experience. It tends to make chemistry more appealing and sometimes even fun."

"Lectures bored me. The book didn't help me. If it hadn't been for PLATO I could not have passed the course, much less done as well as I had. PLATO is excellent"

"Using PLATO wasn't like a book. Here I had to get it right and I could practice the problem instead of just saying "yeah I guess I know that"

These data indicate that students regard PLATO as an important and effective part of chemistry courses and strongly support its continued development and use as an instructional tool to help improve the quality of education at the University.

8.6 UNIVERSITY OF ILLINOIS PLATO CHEMISTRY PROGRAMS (NOVEMBER 1976)

The average completion time in minutes for UI students is given for each lesson which has specified performance criteria for completion.

8.6.1 Introduction to PLATO

Brief introduction to the PLATO Keyboard (10 min)
Ruth Chabay
Introduction to the PLATO keyset for new chemistry students. Emphasizes typing answers at arrows, including use of SUPER and SUB, and use of common branching keys.

Introduction to the Touch Panel (3 min)
Ruth Chabay

Introduction to the touch panel. Explains how the touch panel works, and common pitfalls of using it. Gives student a chance to play with the panel.

8.6.2 General Chemistry Lessons

8.6.2.1 Basic Skills

The Metric System (58 min)
Ruth Chabay
Introduction to the metric system. Introduces metric prefixes, units of length, mass, volume, temperature. Stresses conversion between English and metric units; emphasizes use of dimensional analysis in solving problems.

Scientific Notation (44 min)
Ruth Chabay
Exponential notation, writing large and small numbers correctly in scientific notation, multiplying and dividing using scientific notation.

Conversion Factors and Dimensional Analysis (35 min)
Ruth Chabay
Introduction to the use of dimensional analysis in solving problems. Practice setting up problem solutions by constructing conversion factors, with special attention to using units correctly.

Math Skills Diagnostic Quiz (26 min)
Ruth Chabay
Quiz to measure entering mathematical skills of general chemistry students. Problems involve percent, ratios, solving linear equations, interpreting graphs. Students can find out correct answers, but no instruction is provided.

8.6.2.2 Elements, Athoms, and Nomenclature

Description of the Elements (28 min)
Stanley Smith
Properties and uses of some of the common elements.

Atomic Number and Atomic Mass (31 min)
Ruth Chabay
Introduces concept of atomic number, nuclear particles, counting protons, neutrons and electrons, isotopes, calculation of average mass from isotopic distribution.

Calculation of Molecular Weight (17 min)
Jim Ghesquiere
Practice problems on molecular weights and moles.

Names of the Elements (27 min)
Stanley Smith
Practice on the names and symbols of the elements.

Names of the Common Elements (37 min)
Stanley Smith
Practice on the names and symbols of some common elements.

Name the Element Game
Stanley Smith and Ruth Chabay
Interterminal game in which one student gives the other an element to name.

Inorganic Nomenclature (39 min)
Carolynn Moore
Names of cations, anions, polyatomic ions, acids and bases and multivalent cations.

8.6.2.3 Atomic Structure, Chemical Bonding, Compounds

Valence Electrons (19 min)
Ruth Chabay
Determining number of valence electrons (Groups IA, IIA, IIIA-0) by locating the element in the periodic table. Periodic relations of common ions formed by elements in these groups.

The Aufbau Principle (35 min)
Ruth Chabay
Introduction to electron configuration. Constructing orbital occupation diagrams for elements other than rare earths.

Writing Electronic Configurations (38 min)
Ruth Chabay
Introduction to 1s 2 notation for representing electronic configurations. Correclation of electronic configuration with location in the periodic table.

Historical Introduction to Atomic Theory (40 min)
Ruth Chabay
Student performs simulations of experiments done by Dalton and Rutherford, leading to determination of relative and absolute masses of atoms.

Ionic Bonding and Lewis Structures (27 min)
Ruth Chabay
Writing Lewis dot structures to represent ions and ionic compounds. Recognition of common types of ionic compounds (acids, bases, and salts).

Covalent Bonding and Lewis Structures (46 min)
Ruth Chabay
Discussion of the principles of covalent bonding. Writing Lewis dot structures for covalently bonded compounds. Covers single and multiple bonds, but not resonance.

8.6.2.4 Balancing Equations, Stoichiometry

Balancing Chemical Equations (26 min)
Stanley Smith
Pratice problems on balancing simple chemical equations.

Balancing REDOX Equations (31 min)
Stanley Smith
Practice problems on balancing simple oxidation-reduction equations.

Molecular Formulas and % Composition (83 min)
Ruth Chabay
Counting atoms in molecules, definition of empirical and molecular formula, calculation of molecular weight. Calculation of % composition; finding the empirical formula from % composition data.

Calculations Using Chemical Equations (65 min)
Ruth Chabay
Elementary chemical stoichiometry - meaning of a chemical equation; mole-mole, mole-weight, and weight-weight problems.

Solutions: Concentration (46 min)
Ruth Chabay
Definition of molarity, calculation of molarity of a solution. Solving problems involving molarity, including solution dilution problems.

8.6.2.5 Chemical Equilibrium

Chemical Equilibrium & Le Chatelier's Principle (32 min)
Ruth Chabay
This lesson leads the student through a tutorial dialog in which a non-chemical system is used as an example to define equilibrium, define K e q, and illustrate Le Chatelier's principle. Not much mathematical calculation is required.

Chemical Equlibrium and Weak Acids (68 min)
Ruth Chabay
Introduction to chemical equilibrium using a non-chemical system; discussion of acid dissociation. Practice using K a to calculate ionic concentrations for weak acids.

Equilibrium Problems (16 min)
Jim Ghesquiere
Practice problems on chemical equilibrium.

K e q, K a, K b and pH (20 min)
Jim Ghesquiere
Relations between K e q, K a or K b. Calculation of acid-base equilibrium concentrations, pH and equilibrium constants.

Chemical Stoichiometry (10 min)
Jim Ghesquiere
Problems on the use of balance chemical equations.

Ideal Gas Laws (67 min)
Stanley Smith
Experimental derivation of ideal gas laws.

Solving Ideal Gas Law Problems - part I (24 min)
Ruth Chabay
Reviews the algebra necessary for manipulating the ideal gas law equation; practice rearranging the equation and solving problems, including converting torr to atm and C to K.

8.6.2.6 Thermodynamics

Law of Hess (37 min)
Jim Ghesquiere
Endothermic and exothermic reactions, addition of equations to determine enthalpy of a reaction.

8.6.2.7 Laboratory Techniques

Use of the Analytical Balance (34 min)
Stanley Smith
How a single pan balance works, reading the scales, how to operate.

How to Read a Buret (9 min)
Stanley Smith
How to use and read a buret. Uses photographs of buret on microfiche for practice problems.

Freezing Point Depression Experiment (81 min)
Jim Ghesquiere
Determination of molecular weight with simulated experiment on freezing point depression of benzene solutions.

8.6.2.8 Acid-Base Chemistry

Acid-Base Reactions (13 min)
Stanley Smith
Practice problems in setting up simple acid-base reactions.

Introduction to Acid-Base Titrations (48 min)
Stanley Smith
Equations, calculations, indicators, setting up titration experiment, and reading a buret.

Introduction to Acid-Base Titrations (52 min)
Ruth Chabay and Stanley Smith
Microfiche version of introduction to titrations.

pH and Titration Curves (17 min)
Jim Ghesquiere
Calculation of H + and pH, titration of weak acids and bases, titration of diprotic weak acids.

8.6.3 ORGANIC CHEMISTRY LESSONS

8.6.3.1 Structure and Nomenclature

Organic Nomenclature, part 2. (44 min)
Stanley Smith
Common and IUPAC names of alkanes and alkyl halides.

Organic Nomenclature, part 2 (26 min)
Stanley Smith
Writing of structural formulas for alkanes and alkyl halides. Recognition the functional groups: ROH, RNH 2, RCHO, RCOR, RCOOH, RX, RCONH 2.

Names of Organic Functional Groups (42 min)
Stanley Smith
Provides drill on the recognition of common functional groups.

Conformations of Alkanes (24 min)
Stanley Smith
Three dimensional representation of molecules, conformations of ethane, propane and butane, energy barriers to rotations about single bonds, Newman projection formulas.

Conformations of Cycloalkane (38 min)
Stanley Smith
Heats of combustion of cycloalkanes, strain energy conformations of 3,4,5 and 6 membered rings, axial and equatorial groups.

Bonding in Carbon Compounds (11 min)
Stanley Smith
Brief review of sigma and pi bonds.

Optical Acitivity (59 min)
Stanley Smith
3-D representations of organic molecules, mirror images recognition of chiral molecules, measurement of the rotation of 2-butanol, optical purity.

8.6.3.2 Functional Group Chemistry

Free Radical Halogenation (57 min)
Stanley Smith
Mechanism of free radical chlorination and bromination of alkanes. Calculation of the heats of reaction from bond energies.

Alkene Chemistry (44 min)
Stanley Smith

Nomenclature of simple alkenses, addition HX, water, halogens, and hydrogen. Hydroboration. Animations of hydrogenation and bromine addition to double bonds simulated experiment on effects of concentration of anions on the reactions of bromonium ions.

Alkene Review Problems (28 min)
Stanley Smith
The student is given a group of compounds and reagents and must find interconversions between them by touching the corresponding reactant, reagent and product.

Alcohol Chemistry (89 min)
Stanley Smith
Common and IUPAC names of alcohols. Preparation by reduction of C=O, hydration, hydroboration, hydrolysis of HX, and Grignard additions. Reactions: oxidation, conversion to RX, dehydration, salt and ether formation.

Alcohol Review Problems (29 min)
Stanley Smith
The student must indicate interconversion between Compounds involving alcohol - carbonyl group oxidation and reduction and Grignard addition reactions.

Substitution and Elimination Reactions (43 min)
Stanley Smith
Simulated experiments on the ethanolysis of n-BuBr and t-BuBr. Animations of substitution and elimination reactions.

Problems on Substitution and Elimination Reactions (33 min)
Stanley Smith
The student is asked to indicate the starting materials, reagents and products for some substitution and elimination reactions.

Addition to Carbonyl Croups (42 min)
Stanley Smith
Simulated experiment to determine mechanism of cyanohydrin formation. Hemiacetals, acetals, etc. Experimental determination of pH rate profile for oxime formation. Phenylhydrazone and DNP formation.

Reactions of Aldehydes and Ketones (55 min)
Stanley Smith
Enolization, H-D exchange, kinetics of bromination experimental comparison if reaction with Br 2 and I 2. Kinetics of racemization at carbon. Aldol condensation.

Aldehyde and Ketone Practice Problems (23 min)
Stanley Smith
Practice problems in recognition of starting materials and products in the preparation and Reactions of Carbonyl compounds.

Arene Chemistry (58 min)
Stanley Smith
Mechanism of electrophilic substitution. Directive effects.

Multistep Aromatic Synthesis (39 min)
Stanley Smith
Synthesis of mono and di-substituted aromatic compounds Multistep synthesis in which student supplies reagent and computer draws structure of product.

Aromatic Synthesis Game
Stanley Smith
Interterminal game in which one student makes up a compound for the other player to try to synthesize.

Drawing Kekule Structures of Arenes (60 min)
Stanley Smith
Students indicate the positions of the double bonds in Kekulé structures for 5 different arenes.

Carboxylic Acids (35 min)
Stanley Smith
Structure, nomenclature and acidity of carboxylic acids.

Esters of Carboxylic Acids (28 min)
Stanley Smith
Preparation and Reactions of esters. Simulated experiments to determine mechanism of esterification, labeled oxygen exchange, and hydrolysis.

Derivatives of Carboxylic Acids (56 min)
Stanley Smith
Preparation and reactions of esters, acid chlorides, anhydrides and amides.

Review Problems on Carboxylic Acids (25 min)
Stanley Smith
Review problems on the interconversion of acids, esters, amides, acid chlorides and amides.

Introduction to Multistep Aliphatic Synthesis (35 min)
Stanley Smith
Outlines some approaches to multistep synthesis using Grignard reactions. Student must prepare several compounds by indicating reagents for each step with

the computer drawing the structure of the product.

Aliphatic Synthesis Game (66 min)
Stanley Smith and Ruth Chabay
Two-student race involving multistep aliphatic synthesis from randomly chosen starting materials. Uses Grignard reactions and simple alcohol - carbonyl group interconversions.

Aliphatic Synthesis Game
Stanley Smith and Ruth Chabay
Interterminal version of the synthesis game.

8.6.3.3 Spectroscopy

Introduction to Nuclear Magnetic Resonance (29 min)
Stanley Smith
NMR signals from protons. Recognition of types of protons in organic compounds. Chemical shift and chemical shift scales.

NMR Spin-Spin coupling (35 min)
Stanely Smith
Proton spin-spin coupling and the n+1 rule. Allows the student to calculate AB and AB 2 spectra from J and values of the chemical shift.

Interpretation of NMR spectra (102 min)
Stanley Smith
Identification of compounds from empirical formula and the proton NMR spectrum. Compounds show first order spin-spin coupling.

Interpretation of NMR Spectra (short version) (52 min)
Stanley Smith
Same as the long version except has fewer problems and doesn't use microfiche to show real spectra.

Infrared Spectroscopy (70 min)
Stanley Smith
Provides brief background in recognition of functional groups and practice problems in identification of alcohols, aldehydes, ketones, amines, acids, amides, nitriles, etc.

Infrared Spectroscopy - Short Version (51 min)
Stanley Smith
Brief introduction to IR and practice problems on alcohols, amines, aldehydes, ketones and esters.

8.6.3.4 Carbohydrates and Amino Acids

Carbohydrates, part 1 (22 min)
Harvey Myers
Classification and nomenclature of monosaccharides.

Carbohydrates, part 2 (37 min)
Harvey Myers
Structures of Monosaccharides, Haworth Projection formulas. Mutarotation.

Carbohydrates, part 3 (42 min)
Harvey Myers
Reactions of monosaccharides, Kiliani-Fisher synthesis, Ruff degradation, osazone formation, HIO 4 oxidations.

Clucose Mutarotation (33 min)
Stanley Smith
Simulate laboratory separation of the enantiomers of glucose and measurement of optical activity and mutarotation.

Names of Natural Amino Acids (42 min)
Stanley Smith
Drill on the names and structures of natural amino acids.

8.6.3.5 Qualitative Organic Analysis

Reactions use in Qualitative Analysis (52 min)
Stanley Smith
Review of some classification tests. Practice problems in interpretation of test results.

Qualitative Organic Analysis (33 min)
Stanley Smith
Specific test results are made available and the student must identify the compound from a list of possibilities..

Qualitative Organic Analysis (119 min)
Stanley Smith
Students identify unknown compounds by asking questions about the results of laboratory experiments on the compound.

8.6.3.6 Advanced Topics

Mechanism of Semicarbazone Formation (80 min)
Stanley Smith
Advanced lesson on semicarbazone formation. Requires that each student set up conditions, run, and calculate rate constants for various substituted benzaldehydes in both acid and alkaline medium, and then make appropriate rho sigma and pH rate profile plots and provide a mechanistic explanation of the data.

8.6.3.7 Organic Laboratory

Melting Points and Mixed Melting Points (17 min)
Stanley Smith
Effect of purity on melting point, phase diagrams, use of mixed melting points for identification.

Crystallization and Recrystallization (22 min)
Stanley Smith
Effect of temperature on solubility, purification by recrystallization, fractional crystallization.

Crystallization Experiment (27 min)
Stanley Smith
Simulated experiment on the purification of naphthalene by recrystallization.

Introduction to Distillation (30 min)
Stanley Smith
Boiling points, phase diagrams, simple distillation, fractional distillation, and azeotropes.

Fractional Distillation Experiment (15 min)
Stanley Smith
Simulation of the fractional distillation of pentane and hexane. The student controls pot temperature and collects fractions. He must separate the mixture. After doing the assigned problem the student can make up his own distillation problem and specify the boiling points of the components and the number of plates in the column.

9. PLATO SYSTEM SOFTWARE

9.1 INTRODUCTION

The TUTOR language and other components of the PLATO system software have been developed by a group of permanent staff members, aided by visiting staff and by part-time graduate, undergraduate, and high school students. Section 9.7 lists the principal people involved, with a brief indication of each person's major area of concentration. This system software represents the highest state of the art for the creation and delivery of computer-based educational materials[1]. This report will attempt to give an overview of the features of the PLATO system software together with a description of the environment and the processes in which and by which the present level of development was reached. Some indications will also be given of the areas of further development likely to be pursued in the future.

9.2 LANGUAGES FOR COMPUTER-BASED EDUCATION

PLATO IV system software development began in earnest with the delivery of a CDC 6400 computer in September 1970. While some basic design work had been done prior to this time, the main preparation for the new work was the extensive experience gained on the PLATO III system. PLATO III used a CDC 1604 computer to run 20 graphics terminals simultaneously (there were 70 terminals but only 20 ports). PLATO III was unusual not only in using graphics terminals

[1] For some independent assessments, see the article by A. H. Hammond in Science 176, 1110 (1972) and the talk by S. K. Lower, "Making C.A.I. Make a Difference in College Teaching," NATO Advanced Study Institute on Computers in Science Education, Louvain-la-neuve, Belgium, July 1976.

but also in holding all executing programs in central memory to avoid the delays inherent in most multi-terminal systems which swap programs to disk or drum. Particularly after the creation of the TUTOR language in 1967, many teachers wrote PLATO III lessons and taught classes using these materials. From such operational use were gained extensive data on the memory size and the processing power required to support class use, as well as a wealth of less formal but equally important critiques and suggestions from teachers and students as to how the system should be improved. While PLATO III was a vitally useful testbed, its hardware and software architecture was not suitable for replication, whereas it was hoped that the design for PLATO IV would lead to a system capable of wide-scale expansion.

Both in the late sixties and now, there have been three major classes of programming languages or systems for preparing computer-based educational materials. The first class includes standard languages such as FORTRAN or BASIC, sometimes augmented by a few special options for the purposes of "CAI" (computer-assisted instruction). It turns out in practice that such languages, while eminently suitable for scientific and administrative programming, are lacking such a large number of crucial CAI support facilities as to make them quite difficult to use for CAI purposes[2]. Moreover, almost all such general-purpose languages were originally designed for use with non-graphical line printers and teletypes. While graphics packages have been grafted into some versions, there is reason to believe that this leads to less satisfactory structures than can emerge from a language designed specifically for interactive graphics terminals.

The second class includes specifically "CAI" languages, such as COURSEWRITER and COPI. Most such languages were designed with a good understanding

[2] See the Lower paper of Reference 1 for a discussion of this point.

of the specifically "CAI"-oriented features missing from the general-purpose languages; but with a lamentably restricted view of the breadth and complexity of interesting educational interactions between teacher and student as mediated by a computer system. Such languages made it easy to program simple multiple-choice or short-answer questions, but very difficult to create computationally-complex interactions, with rich interconnections of subroutines. Not only are such languages notoriously weak in calculational ability (though PLANIT is an exception in this area) but like the general-purpose languages they generally have no graphics features (except for the now-defunct IBM 1500 version of COURSEWRITER). The lack of graphics features stems from the availability of inexpensive non-graphics terminals plus the lack of recognition of the vital necessity of graphics in most teaching situations.

The third class of mechanisms for creating materials are those systems such as the "General Logic" (pre-TUTOR on the PLATO III system) and the present TICCIT system, in which teachers feed items into a database manipulator. For example, the system may ask the teacher to type a question, then ask the teacher what is a correct answer and what are some wrong answers. These items are stored in a database and used to construct multiple-choice questions for the student. The big advantage of such systems is that a teacher can create large quantities of materials without learning a programming language, as long as the materials fit the formats built into the system. The big disadvantage is that it is very difficult in such environments to explore qualitatively new kinds of interactions. Depending on the sophistication of the system, even minor departures from the standard presentations may be impossible to achieve. On the other hand, as more and more flexibility and options are added to such a system, it is often the case that the system ceases to be easy to use. It can even be more difficult to use than a true programming language, while a true language offers far more flexibility in the long run. Moreover, if a true language is available users will be able to create their own format-oriented systems if they so desire, whereas the existence of a format-oriented system does not permit the creation by users of a true language; the situations are not symmetrical.

TUTOR on the PLATO III and PLATO IV systems does not fall into any of these three classifications. TUTOR has the computational capabilities of other general-purpose languages, far more powerful response handling than "CAI" languages, and is specifically designed for interactive graphical-display terminals. It, of course, also permits the creation of format-oriented lesson construction subsystems, and there exist a number of rather elaborate machines of this kind implemented through TUTOR. Substantial portions of the system software itself are written in TUTOR, including editors, sign-in procedures, disk management routines, etc.

Most computer languages are designed to be independent of the hardware environment. TUTOR on the other hand was conceived and implemented not as a self-standing entity but as one component of an integrated PLATO system, and the nature of the terminal, the communications network, and the computer architecture (especially the unusual computer memory hierarchy) all influence the structure of the language in many explicit and implicit ways[3]. This somewhat unorthodox approach has the advantage of permitting users fully to exploit the available resources. Moreover, the fact that the TUTOR language is entwined with the PLATO operating system means that TUTOR lessons have ready

[3] For a description of the PLATO hardware and software environment, see B. Sherwood and J. Stifle, "The PLATO IV Communications System," Computer-based Education Research Laboratory, Urbana, Illinois, 1975.

access to such administrative details as the sign-on name of the person who is executing the lesson. Where most time-sharing systems support many different languages, TUTOR is the only interactive language available on the PLATO system. (Many users have written small-scale languages in TUTOR, such as subsets of BASIC, FORTRAN, and PL/I for short student jobs, and a few users have access to batch processing in standard languages. TUTOR is, however, the only system-supported interactive language.) This has led to an expansion of TUTOR features to provide for many different kinds of programming needs, needs which would normally be met by many separate languages. Supporting only one language has also made it possible to provide much better on-line documentation and consulting aids than would otherwise have been possible. All of these aspects of TUTOR distinguish it from most other computer languages.

9.3 SOFTWARE FEATURES AVAILABLE TO PLATO AUTHORS

It is useful to list some of the more unusual software features available to PLATO authors. In some cases more powerful implementations of individual features exist in other systems (for example, three-dimensional rotations in sophisticated computer graphics systems or syntactical sentence analysis in artificial intelligence projects), but PLATO and TUTOR attempt to provide adequate support in many areas in order to bring together all the essential components of computer-mediated interaction. While some of the following facilities are unique to PLATO, it is perhaps more significant and more unusual that these facilities have been integrated into a useful whole.

(1) Graphics at the basic level. The structure of the language and the specific graphics commands are basic to TUTOR, not grafted onto a text-oriented language. The features include relative and scaled graphics as well as graphics in absolute screen coordinates.

(2) Single-key interaction. This property, which is shared among the communications hardware, the computer memory architecture, and the TUTOR language, makes it easy to handle individual input keys with a response time of one-eighth second. This makes possible greatly heightened interaction in comparison with the more typical "end-of-line" processing of standard time-sharing systems.

(3) Interactive display creation. This is a property of the language and of the source code editor which makes it easy for authors to place text and drawings directly on the screen and receive an automatically generated source-language TUTOR program corresponding to that display. This automatic programming feature makes display creation far more accessible than it would be if it were available solely in the language itself.

(4) Area graphics. On PLATO III authors could create individual characters or whole alphabets in order to escape the common restriction to the standard alphabet. On PLATO IV this capability is further exploited to provide a range of graphics capabilities rather different from line drawings. Authors have convenient tools for creating sets of 8x16 dot-matrix characters which can be combined to form still and moving pictures of objects. This yields a much more compact representation for many purposes than do line drawings. Corresponding to the original purpose of area graphics, there are now available many foreign-language alphabets and tools for using them, including leftward-going alphabets such as Persian.

(5) Concept judging[4]. An unusual facility for handling natural-language dialogs is provided by the ability to define a vocabulary of thousands of words and to list hundreds of sentence "concepts" involving these words. The ability to specify synonyms in the vocabulary permits a single concept to represent a large number of student inputs. Further author control is possible by associating numerical parameters with vocabulary items. Authors can also specify many options to control the judging machinery itself. The judging process makes novel use of the data structure of the stored (author-supplied) data and properties of the computer architecture (properties of individual computer instructions and the memory hierarchy), making it possible to respond in a fraction of a second to rather complex inputs. An additional unusual feature of the sentence-judging algorithms is the detailed feedback provided to the student, showing which words are misspelled, incorrect, etc.

(6) Spelling. There is a spelling algorithm which operates on a unique global basis and avoids detailed character-string processing. (This algorithm can distinguish between a misspelling

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[4] P. Tenczar and W. M. Golden, "Spelling, Word, and Concept Recognition," Computer-based Education Research Laboratory, Urbana, Illinois, 1972.

and a true word difference in a few microseconds. The extreme quantitative speed of this algorithm yields a qualitative difference in the ways misspelling can be handled.

(7) Normal mathematical notation. The form of TUTOR calculational statements is essentially that of standard mathematics rather than that of computer languages. Implicit multiplication (omission of the multiplication sign) is permitted wherever it is unambiguous. Exponentiation is shown with superscripted powers (which is possible because of the graphics features of the terminal). Additional uncommon TUTOR calculational facilities include bit- and byte-manipulations, whole-matrix operations, and the ability to use an arbitrarily-complicated calculational expression anywhere in the language that a simple integer could appear.

(8) Algebraic judging. Drawing upon the fact that expressions are written in standard mathematical form, additional facilities make it easy to judge both the algebraic correctness and the detailed form of a student's algebraic response. Also, a unique feature handles scientific units on a true dimensional basis. Student character strings can be compiled and repeatedly executed by a TUTOR command, which gives authors access at execution time to the TUTOR expression compiler.

(9) Text-substitution tables. A table can be defined which converts, keypress by keypress, what is typed by the student into other text. This facilitates dynamically changing the keyset layout.

(10) Communications facilities. A rich array of communications tools provides rapid information transfer among the many users. There are public and special-interest forums, on-line consulting services (in which the consultant can look at the author's screen remotely), on-line typing interaction (the two users type messages to each other at the bottom of their screens), and personal notes (sent electronically from one user to another, by name). Among the many important administrative uses of the facilities is the continual flow of detailed suggestions from the large user community to the system software staff.

(11) Tools for running classes. Users can use TUTOR not only to write lessons but also to write programs for managing student progress through a curriculum of many lessons and for producing reports on student progress. One important tool is the "router" lesson through which a student passes upon sign-in and which can make algorithmic decisions on where to send the student or what choices to provide the student. A particular router of general utility is supported by the system staff, and many users also have written, special-purpose routers.

(12) Attaching other devices. A property of the terminal, the communications hardware, and the TUTOR language is the relative ease with which additional input and output devices can be attached and manipulated. These devices have included touch panels, microfiche projectors, audio response units, typewriters, and laboratory equipment.

(13) Rapid compilation. The structure of the language, the disk system, and the computer memory hierarchy combine to make it easy for authors to compile, test, and revise a lesson. It normally takes only a few seconds to move from editing source code to executing the program, and transitions from editing to executing and back again are done with a simple keypress. The speed and ease of these operations is a key element in helping authors quickly find solutions to programming tasks.

A few PLATO users, including the software staff, are permitted to run batch programs using any of the facilities available under the standard Control Data NOS operating system, including assemblers, compilers, loaders, and other utility packages. Such programs run at a lower priority than TUTOR and take advantage of the fact that in a very large system the left-over processing momentarily available, due to statistical fluctuations in the load, can add up to a significant resource. This is an additional advantage of large systems over small ones. Access to these batch-processing facilities is conveniently made through standard PLATO terminals. Not all the accounting and scheduling machinery is yet in place to offer batch processing to all users. It should, however, be mentioned in this connection that major users can run batch jobs written in TUTOR on a timed basis. A typical use of this facility is to do daily automatic sorting of student-associated data in large courses.

9.4 DEEPER SOFTWARE STRUCTURES

While the above list of features includes many of the most important and most distinctive software aspects of PLATO, there are a number of other, deeper software structures less obvious to the user but equally important in providing quality service.

(1) Electronic program swapping. The use of CDC's Extended Core Storage (ECS) for program swapping instead of disk or drum has major qualitative and quantitative impacts on all aspects of the PLATO system. It makes it possible to handle hundreds of graphics terminals with fractional-second response times. It makes single-key interaction feasible: every keypress is treated as a complete job for the central processor, not by a less intelligent communications processor. The "unit" structure of TUTOR coupled with the high transfer rate of ECS makes possible a unit-by-unit swapping scheme that results automatically in an invisible segmentation or overlay structure for large programs. The rapid ECS transfer rate is also heavily exploited at the TUTOR language level and elsewhere in the system software in order to handle various kinds of transfer and sorting tasks.

(2) The "formatter" subsystem. The formatter converts generalized terminal output data into optimized data streams for the particular kind of terminal and the present state of the terminal. It also maintains smooth uninterrupted output to the terminals, which among other things makes possible smooth-flowing animated drawings. It cooperates with error-detection machinery in the terminal to correct transmission errors when they occur.

(3) The disk subsystem. Disk file structures are simple, and file pointers are held in ECS, thus eliminating one level of disk accessing. The performance and reliability of the disk subsystem permit hundreds of authors simultaneously to perform editing and other disk activities with nearly zero loss of stored data, all of which are kept on-line at all times.

(4) Test versions. Assembly and loading techniques have been developed which permit completely new versions of the TUTOR software to be brought up in a few minutes. This makes it possible to make rapid evolutionary changes in the system software. Normally, a tested production version is run during the day, and an experimental version is run after 10:00 p.m. every night.

(5) Source conversions. Usually changes to the TUTOR language have been additions to existing capabilities. Sometimes, however, it gradually becomes clear to the users and to the system software staff that some existing TUTOR syntax structure is poor and could be greatly improved. Since all source files are kept on-line at all times, it is possible to process existing TUTOR files with a program (written in TUTOR) to convert from the old format to the new. This has been done many times and has contributed to keeping TUTOR a living language rather than a dead one. Of course, when conversions are performed the on-line description of the language is also changed. An attempt has been made to avoid putting too much detail into written descriptions of the language, in order to preserve this capability to change the form of the language.

We have outlined where we started, and by listing some of the major characteristics of the PLATO system at present, where we are. In the next section we will attempt to identify what factors influence most strongly the past and future directions of the system software development.

9.5 THE DRIVING FORCES FOR SYSTEM SOFTWARE DEVELOPMENT

The single most important driving force behind PLATO system software development has been the recognition of the subtlety and complexity of education. One immediate corollary is the insistence on using terminals with adequate communications facilities, including graphics capabilities in particular. Problems and opportunities associated with the graphics features of the PLATO IV terminal have taken a goodly share of the efforts of all staff members. While often not thought of as graphics elements, even text operations have involved a great deal of work of an essentially graphics-oriented nature, in order to handle multiple alphabets, subscripts, superscripts, erasure problems and even leftward alphabets. There has been a lengthy evolution in the TUTOR graphics commands. For example, as recently as the summer of 1976, a major conversion was performed to rationalize the three major sets of graphics commands (absolute, relative, and scaled).

The requirement of complex interaction with fractional second response, a requirement imposed by human needs, means that a short but intense burst of complicated processing must be performed for each user input. This requires a processor with high speed and with large amounts of useful memory. While a quality interaction with just one user requires highly sophisticated computer resources, it is economically necessary to share such resources among many users (with the computer working for other people between inputs made by the first user). This requires high-speed transfer between the execution memory and the swapping memory, which holds all the (momentarily) inactive programs. A detailed investigation of all these factors led to the choice of the CDC 6400, a large-scale scientific computer with ECS for the electronic swapping memory. ECS has a transfer rate one hundred times higher than disks or drums and an access time more than one thousand times better than disks or drums. These unique properties in turn have colored all aspects of the PLATO system software.

Another major influence on PLATO system software has been, in a certain sense, an environment of scarcity. Attempting to run hundreds of graphics terminals has meant that the average amount of processing per second per terminal and the amount of memory per terminal have had to be uncomfortably small. Much staff time and effort is continuously expended on finding ways around these stringent limitations. Perhaps the most dramatic and innovative example of these efforts is represented by the spelling and concept-judging features of TUTOR, in which the normally very slow and expensive character-string processing of most systems has been replaced by techniques which work better yet work hundreds of times faster. A less dramatic example is the simultaneous sharing of single copies of lessons in ECS by many students. Another very scarce resource has been the transfer rate to databases on disks. Because it was feared that disk transfer rates might be the limiting factor determining the number of terminals which could be handled, great efforts were made to hold down the need for making disk accesses. With improved disk equipment and improved disk software it has become possible to loosen these restrictions.

Availability to the system staff of a large, dedicated computer system has had a profound impact on what could be developed and at what rate. The capability to prepare and test daily new versions of the system software has been of inestimable value. It may seem wasteful of expensive resources to allow a group to "play" in this way. Shouldn't the software be carefully designed, implemented, and then altered only in minor ways thereafter? The difficulty is that education is an extremely complex human endeavor, and no person or group can design in advance an adequate software system to support education, unlike the case with more narrow endeavors, such as administrative or scientific computing. An adequate system can only evolve continuously in actual use, which requires the facilities to make rapid changes in response to discovered needs of the users.

Aside from the essentially technical influences discussed above, the biggest impact on the PLATO system software development comes from the large user community. The large size of that community, in direct, instantaneous contact with the developers (through on-line forums and personal notes as well as through personal contacts), is in itself an unusual factor. Simultaneous pressures from the French professor who needs improved judging of French syntax, from the teacher of veterinary medicine who has a good suggestion on how to simplify the use of a touch panel, and from the chemist who needs a better way to manage PLATO classes involving hundreds of students all drive the development. Traditionally, requests for system modifications filter through various layers of user groups to an isolated system software staff. In the PLATO case, however, one system is itself large enough to provide a critical mass of electronically immediate input. The large number of "electronically-local," (though nationally distributed) users both insures the breadth necessary to identify common problems and provides software staff with the important psychological gratification of seeing their work needed and used. This latter point may, in fact, be quite important: many desirable PLATO tools might not have been built on a smaller system, where wide-spread use would not have been apparent.

A particularly important segment of the user community is formed by the system software staff itself. In the development of far too many systems (computer systems and others as well), the developers have not themselves been users. The PLATO software staff members use PLATO and TUTOR constantly in their daily work, both for creating system software and for controlling and monitoring system operations. This forces the staff members to pay close attention to the needs of all users, themselves included. Not only is much of the system software written in TUTOR, but all of the file editing is done with the same text editor used by all users, files are maintained under standard TUTOR formats, and standard PLATO terminals are used. Inadequacy of the text editor or loss of data due to disk subsystem malfunction would affect staff members as much as it would affect other users. When it became apparent that additional search features were required for editing system software files, these features were provided to all users. In general, an attempt is made to have as few "privileged" options as possible, to insure that staff members remain in close contact with the real problems of users.

Now that many of the facilities required for instruction and the management of instruction are in place, it appears as something of a surprise that PLATO can be and is being used for many other purposes. One way of looking at this situation is to say that providing interactive education by computer is one of the most difficult of all computer programming tasks. Once adequate tools are avilable for this difficult and subtle kind of interaction, the system has reached a level of such sophistication that other, non-instructional interactive computing tasks become easy. Evolutionary user pressure is increasingly exerted in the direction of improved database-manipulation tools, additional forms of communications, better administrative and clerical word-processing facilities, etc. It appears that reacting to these new desires will form one major theme of future system software work.

9.6 THE FUTURE

In addition to user pressure for improved non-instructional facilities, there are a few other major development activities which can be foreseen today. One of these areas consists of efforts to exploit the novel capabilities of a new generation of "PLATO V" terminals. It is intended to add several hundred of these micro-processor-based terminals to the Urbana system. Because there is a loadable program memory in the terminal, the possibilities for exploiting the terminal are quite open-ended. It is already apparent that certain kinds of display generation can be performed more rapidly at the terminal, but what other tasks it can appropriately perform are not at all clear, nor is it clear precisely what impact these terminals will have on the central computer software. While the terminal will certainly free the central computer from many routine tasks, it is likely that processing overall will rise in the central computer in order to exploit fully the new capabilities of the much more powerful terminals.

Another future and current development theme is that of networks--tying many PLATO systems together much as local telephone exchanges are tied together. There is already a line between the Urbana PLATO system and CDC's Minnesota PLATO system. Over this line flow curriculum materials, programs, notes, etc. Much remains to be done to improve this facility and to connect all PLATO systems together. This link has already proved to be invaluable in unifying the various user and development communities. A related area of work has led to embedding PLATO software in the standard CDC "NOS" operating system, to simplify the distribution of new versions of the PLATO software to all PLATO systems. There will be continuing efforts to ensure that all PLATO systems will be compatible and have the latest version of the software at all times.

It appears that future PLATO systems will use larger numbers of increasingly less expensive processing units, sharing memory for common data. It is already the case that the Urbana system has two mainframes, each with two central processing units, sharing ECS through which communications between the mainframes flow. The four central processing units share tasks in rather straightforward ways at present. Future developments are intended to lead to greater flexibility in such task-sharing.

9.7 SYSTEM SOFTWARE STAFF

This is a list of people who have contributed directly to PLATO IV system software development. An attempt has been made to give a brief description of the area of emphasis for each person, although in many cases the person may have been involved in one way or another in many aspects of the system software.

Paul Tenczar, Head of the System Software Group
Invention of the TUTOR language; all areas; interaction speed; sentence judging and spelling; unit-swapping structure; micro tables; foreign-language versions.

David Andersen
All areas; ECS management; character sets; calculation definitions, functions, byte manipulations; graphics; accounting; student data; multi-mainframe software.

Bruce Sherwood
All areas; calculation compiler; algebraic and dimensional-units judging; graphics.

Richard Blomme
All areas; disk subsystem; graphics; interactive display generation; databases; terminal input/output.

Donald Lee
Formatter; operating system; assemblers.

Michael Walker
Operating system; disk subsystem.

Robert Rader
Operational aspects; numerical display; databases.

Christopher Fugitt
Operating system.

Donald Shirer
Scaled graphics; matrix operations.

William Golden
Spelling algorithm; consulting in many areas.

Ruth Chabay
Class-management tools (routers, report generators).

James Parry
Terminal output; graphics; external devices.

Masako Secrest
Operating system.

David Frankel
Text editor and related tools.

Kim Mast
Personal notes (electronic mail).

Phil Mast
Calculational language structures; printing.

Marshall Midden
Text and graphics editors; general maintenance.

Lawrence White
Graphics; language conversions.

David Woolley
On-line forums.

Doug Brown
Printing of files.

Brand Fortner
Line-drawn character sets; sorting routines.

Sherwin Gooch
Search routines.

David Kopf
Early ECS management scheme.

Allen Avner
Student data design; datakeeping on system use.

[redacted]
File searches; error diagnostics.

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APPENDIX 5.1

Trends in Data from the Elementary Reading Project

Robert Yeager

This paper is an informal analysis of data collected by the PLATO Elementary Reading Curriculum project (PERC) as of February, 1976; formal analysis of the data will be completed at a later date. This informal analysis is presented to indicate the current trends that are developing, and to show the types of questions PERC can hope to answer.

1) General Information

As of early February, PERC was running about 300 students per day from 25 classrooms. A total of 783 students have taken PERC activities so far this year; each student has been on the system an average of 6.2[illegible]5 hours, and an average of 27 days.

A total of 88,925 activities had been executed as of 02/04/76; each activity lasted an average of 2 minutes and 4[illegible] seconds.

2) Students Succeed in PERC Activities

One of PERC's primary goals has been to produce instruction in which the student could experience success. While not attempting to produce "errorless learning", PERC has tried to minimize student failure at the terminal. Data suggests that students are able to perform the specified tasks in most lessons; that same data has been used in the past, and will be used in the future, to improve activities in which students seem to encounter problems.

a) at the end of each activity a single value is set to indicate how well the student performed in that activity; student's performa[illegible] currently distributed:

Good------66%
Fair------13%
Poor-------2%
Bad Data--19%

A total of 54% of the "bad data" is accounted for by one strand of activities which do not set this value; the rest of the "bad data" probably comes from students leaving an activity before the activity is done.

Excluding the "bad data", student's success in PERC activities is distributed:

Good---------81%
Fair---------16%
Poor----------3%

b) All counters used in making decisions about how well a student performed in an activity are being saved; these typically indicate the number of items a student got right or wrong. These counters are collected in order to norm the criteria for the activity, and to point out activities in which students typically have troubles.

Currently, students normally get at least 80% of the items in a lesson correct (this includes only lessons, not tests).

In most activities, a student has to get at least 80% right in order to be marked as having made a "good" performance. The "success" value set at the end of each activity (see -a- above) and the counters used in making that determination indicate that most students perform at an 80% level or better.

That analysis of these counters can lead to better lesson material can be shown by looking at an activity called "The Missing Letter" which teaches alphabetical order. In the 1974-75 school year, the error rate in that activity was over 40%; and the interaction required only a binary choice! The lesson was redesigned and currently shows an error rate of only 10% (N-1607 trials).

While some activities are redesigned because of high error rates, others are totally scrapped and new formats are found.

c) Student correction procedures within an activity appear to be successful in helping a student avoid the same error later on. About 50 activities report detailed information about how each student does on each item. PERC currently requires (in most lessons) that a child make the correct answer in each frame; that is, if he gets an item wrong, he is told that he is wrong, and he is expected to then enter the correct response. That item is then brought back to the student later in the exercise according to several different schedules; for example, the item might be brought back on the second trial after the wrong answer; or all items might be cycled once before incorrect items are brought back for review.

Informal analysis of the raw data suggests that students do perform well on subsequent exposures to an item that had previously been missed. Research by Siegel and Misselt (with college students) shows that such correction procedures promote long term retention. PERC would like to engage in similiar studies with our first grade population, but our current management system inhibits the setting up of specific experimental designs. However, the various review schedules being used in different lessons will be studied to see if they have significant effects on performance within a lesson. The correction procedures described here were not used in the 1974-75 curriculum. At that time PERC followed the principle (experimentally shown in the Stanford Reading Project) that correction did not lead to better retention; i.e., when there's a binary choice (as so many of the PERC activities involve), the child does not need to be forced into making the correct response after an error. Anecdotal and observational data indicated that such a procedure contributed to that sense of a lack of purpose students exhibited in the 1974-75 curriculum; at that time some students were said to view PLATO as recreation only and there was some question as to whether they were attending to the instruction. Reports such as those have been fewer this year and have not directly involved any activities in which the new correction procedure is employed.

d) In summer, 1975, one of PERC's teachers (Mrs.-----) ran a summer course with incoming first graders; she used no other instruction except PLATO; and she administered her own tests with flashcards. Her results showed that students improved in visual skills, letter names, phonics, sight words, and concept words.

The most improvement came in concept words such as "up" and "down". She attributes the success to the PLATO lessons which give the student total sensory involvement in the task; for example, the students use the words "up" and "down" to manipulate something on the screen.

3) PERC Data is Becoming More Valid and More Reliable

Just because students are succeeding in PERC activities does not necessarily mean that they are learning anything. PERC has had a continual problem in making automated decisions about whether a student knows a particular skill. Usually PERC has been guilty of a "false negative error": marking a student as not being able to perform the given skill when in fact the student could do the skill; the other side of this, however, is that students generally can do skills which PERC data says they can.

PERC is not unique in having this problem. Venezsky has tried to put paper and pencil tests on PLATO to do diagnostic testing and reading in the primary grades. He too reports a "false negative error" showing that students with paper and pencil tests generally performed better than students taking tests on PLATO. However, by redesigning the PLATO test he was able to attain approximately equal results.

a) Student performance data for use by teachers seems to be much improved this year. A rather constant complaint during the 1974-75 school year was that the data reported to teachers about individual students was very inaccurate--almost always because the data said the child did not know something the teacher knew he did know.

Performance data was drastically redesigned for this year; and the decision points where that performance data was marked were "externalized"; in the past, decisions about the student's performance were made "on the fly" in the midst of an activity; a single activity might have referred to the performance data base in many different places. All of those decisions were collected so that decisions are now made in one place, at the end of an activity; this was allowed for better inspection of the decision logic and consequent standardization of that logic.

The overall results have been that the data reporting routines are more understandable to teachers. There have been very few complaints this year about the reliability of the current data; and when teachers are asked about the performance data, they have generally indicated that PERC data was fairly close to their own evaluations. While no count has been kept on how often teachers refer to that data, many teachers have been observed as being in the performance data file throughout the year; finally, many teachers have requested hard copy prints of this data which they like to give to parents along with the student's report cards.

b) A formal attempt to validate a couple of the tests used in the phonics and sight word strands has been in progress this year. In this design, students take a PLATO test and their scores are stored away; shortly afterwards, a PERC staff member administers a paper test prepared by ETS on the same material and enters those scores into the computer where they can be compared with the PLATO scores.

Data for the sight word test is not yet available; but preliminary data from the phonics tests indicate that PERC still suffers from a "false negative error"; if PLATO marks a student as knowing a given grapheme/phoneme correspondence, the probability is very high that the student will pass a paper and pencil test; but if PLATO fails a student, the odds look almost even that the student will get the paper and pencil items correct. Both sight word and phonics tests are relatively new and have not been subjected to the revision that other tests in the curriculum have undergone; they follow the pattern discerned earlier that newer materials return a "false negative error" until they are normed and revised.

c) Informal analysis of data from individual activities indicate that the activities usually confirm observation reports. For example, PERC has apparently failed for the third time to teach the students to press a given key (the -help- key) in order to hear an audio message again. Observers report that students simply do not do it unless they have been instructed by an adult; the instructional materials designed to teach that function do not work despite the fact they have been completely redesigned for this year. The data from the activities confirm those observations: while students perform at the 80% level in the instructional sequence, they get just over 50% right in the test (N=11646 trials). The conclusion that has to be drawn is that the skills presented in the instruction are not sufficiently related to the task to be learned.

Another example of how observations of student skills correlate with data from individual activities comes from the diagnostic test on letter names. Observers and teachers report that most students enter the PERC curriculum knowing letter names. Students receive a diagnostic test early in the curriculum which presents an average of 12 of the more difficult letter names; students currently are getting 76% right on this test (N=11623 trials).

Observers also report that our population of students performs well in simple visual skills; the initial diagnostic test on simple word detail skills shows students getting 88% correct (N= 3356 trials).

d) Data from activities on visual discrimination of letter shapes has been kept as a confusion matrix. Generally, letters which research shows as presenting problems for early reading students appear to be the greatest problem for PERC students, too. For example, the greatest difficulties involve b, d, p, and q; other difficulties show up between letters having the similiar slopes and orientations.

e) As described above (2d), Mrs.----- ran a summer class last year in which she used flashcards to test whether or not students were learning. Not only did she find that students did learn, but she also made a rough correlation between her test data and PERC data. She found that in most cases the PERC data accurately reflected her findings; where there were errors, it was almost always a case of PERC marking a skill as unknown which Mrs. ----- found to be known; but such discrepancies were mostly found in the newer, less revised areas.

4) Students Interact Well with Rich but Familiar Formats

A major tenent of PERC has been the importance of good paradigmatic lessons. In its early stages, PERC focused most of its energy on trying to refine lesson designs so that students could easily interact with them. A major problem has been making the rules for how to interact with the lesson as simple as the skill being taught; too often PERC has had to conclude that if a child could figure out how to do the lesson, he probably did not need it!

Therefore, in contrast to the Stanford project, PERC has developed a large number of rich formats; yet there is a continuity amongst formats so that the differences between what a student has to do in order to respond have been kept at aminimum. Thus, the student interest level is kept high by the variety of formats, but his ability to interact with each format is more assured.

a) For the first six sight word tests, there is a correlation of -.91 between position in the curriculum and success in the test. The assumption is made that all of the 24 words tested in those six tests are of equal difficulty (an assumption which will have to be tested); therefore, the significant variable that explains the close correlation is familiarity with the format of the test.

b) In two auditory discrimination tests, there is a marked improvement between the first test on i, p, n, and t (error rate= 27%; N = 5034 trials); and the second test on a, s, b, and l (error rate = 7%; N = 1887). One thing to note here is the smaller n in the second test; error rates are often held artificially low at first because only the faster students have encountered the activity.

c) A sight word activity called "Make a Sentence" has proven to be more difficult than initially anticipated; a couple of activities will have to be designed to precede this activity. On the first use of "Make a Sentence", 73% of the students were unable to successfully interact with the activity (N= 166); yet, on the second use of that activity with new sight words, only 37% could not do it (N= 54).

d) On 13 auditory discrimination drills which all share the same format but differ as to visual reinforcement, the error rates range from 31% (on the second use of the format) to 9% on the (12th use). The correlation between position in the curriculum and success is -.55 which is smaller than one reported above; but there are other variables present in these activities such as the use of visuals in presenting auditory items (discussed below).

5). Students are Successful in Interacting with the Terminal.

Data in this area refers only to how well the students are able to perform the interactions required of them; that is, whether they touch the screen when requested, type on the keyboard when asked, or answer within an allotted time period (usually 30 seconds).

a) Students make an acceptable (though not necessarily a correct) response on their first try 73% of the time. There currently has been no attempt to establish a norm here. PERC has traditionally attended to the problem of making activities easy to interact with. Many activities have been rewritten this year so that the interactions would be more straight-forward.

The data gathered here can be used to identify types of formats which prove especially troublesome for students. PERC has been gathering this type of data for several years; however, much meaningless information was gathered in the past; this year's data has been collected in a way that should facilitate a more formal analysis.

b) Students appear to remediate their own procedural errors. An old principle PERC has followed has been to withhold remediation for procedural errors (e.g., touching an unrecognized area) until it become obvious that the student really needed further directions. For unrecognized touches, PERC lessons wait until the third such touch has occurred before remediation is offered. From a random sample of interaction (conducted from 1/26/76 through 2/11/76), at least one unrecognized touch was entered in at least 10% of the frames (N= 74472 measured interactions). However, students went on to touch an accepted location in 74% of those cases before a remediation message was needed; and 19% more of the students made an acceptable touch as soon as they heard the remedial message.

In 5% of the cases, students entered unaccepted key presses before they made an acceptable response; this statistic is especially interesting because such data is usually not kept for activities which require typing; therefore, most of this data comes from frames in which the student has been asked to touch the screen. Nevertheless, from the sample described above, 82% of the students stopped typing and made an acceptable answer before the remediation message is triggered by a seventh key press; 10% more students respond to the remedial message leaving another 8% who continue typing up to as many as 60 total keys before being taken out of the activity.

In the sample described above, only 2% of the students waited until the time allotted expired; then 85% of those students responded to the first time-up audio message.

In summary, it appears that students successfully remediate themselves when they make procedural errors. However, some students do need additional instructions in order to enter an acceptable answer.

c) Audio messages have been abbreviated. A constant problem has been audio messages which were so long that the students stopped attending to it; or messages which were long because they contained conditional statements first graders could not follow. Currently, the average audio message takes 2.64 seconds; when all messages shorter than 2.72 seconds are excluded (single words, letters, phonemes, etc.) the average message length is still only 3.81 seconds. The average activity calls for 18 audio messages which yield 49 seconds of audio per activity.

PERC intends to correlate the amount of audio in an activity with other factors which indicate student's success in the activity.

d) Carol Wardrop, an ETS coordinator, observed students behavior at the terminal for her master's thesis. While the data she accumulated was taken from the end of the 1974-75 school year, there is a general consensus that there have been few changes in what she observed; there have been discussions about replicating the study this year with a wider population.

Briefly, Ms. Wardrop used an observation checkoff form to quantify the types of interactions occurring during PLATO instruction. She concluded that the upper two-thirds of the students (as ranked by their teacher) had few problems in interacting with PERC activities; but the lower third were more confused about what they were expected to do.

There is little doubt that there are still things in the PERC curriculum which will confuse that lower third of students despite the fact that PERC has constantly tried to serve those students especially. Using the types of data described above, PERC can identify activities which fail, and further identify principles which can aid in better lesson design.

6) Students Succeed Better in Activities in Which an Audio Message is Correlated with a Visual Display.

One of PLATO's strength is its ability to deliver multisensory experiences. Kathy Lutz, when she was with PERC near its beginning, started some research to find how effective visual displays were; she currently is pursuing that same line with Joseph Rigney at USC. They have conducted several experiments which shows that students (at the college level) retain more when audio information is reinforced by visual displays; moreover, they have formulated a theory that bi-sensory presentations are especially important in developing both analog and propositional faculties in children.

PERC has long tried to support its instruction with visual displays, but has not always been able to afford the cost (in man-hours) of producing the visuals. Consequently a series of 45 activities in the auditory discrimination strand has grown up in which some activities use audio alone while others are augmented with visual displays; the activities are otherwise identical in format. Preliminary data from those activities show that error rates in activities without visual reinforcement are higher than error rates for the mixed approach.

7) Students Choose to do PERC Activities

a) At the end of most PERC activities, students are asked whether they would like to see that lesson again; they respond by touching the words "yes" or "no" on the screen. In the 1974-75 curriculum, it was found that students chose to repeat an activity just over 20%

of the time. In the 1975-76 curriculum, students have again chosen to repeat an activity on an average of 20% (N= 88925 activities). The range of repeat ratios just among strands runs from 5% to 37%; and it is likely that the range among activities is much greater.

PERC is most interested in using this data to demonstrate that students do exercise some meaningful control over their instruction, and to determine formats which students seem to enjoy the most in order to facilitate better lesson design. But this data may have other uses too. For example, several people (PERC staff and teachers) might rank PERC activities according to richness of the interaction; then correlations could be run to see how the richness of the activity affects the repeat ratio. Or, studying which students like to repeat which types of activities could give some insights into learning styles.

b) Few students exit PERC activities before they are done. Students may exit an activity by pressing shift-back or shift-stop; it is not known how many students know how to do this because PERC does not encourage students to prematurely leave an activity. PERC had recorded premature exits from activities in 2% of the cases (N= 86833 activities); some of these are undoubtedly done by teachers who need to get a child off the terminal.

c) Advanced students are allowed to pick their own activities from a simple index. So far there have been 85 choices made involving 35 different activities. A couple types of activities standout as being the most popular amongst these advanced students; these students prefer activities in which their responses have a meaningful effect on the way the activity works (branching stories, for example).

8) The Management System has Performed Well Although Some Inadequacies are Becoming Apparent.

The management system has delivered instruction almost without error during this year; the only errors that have occurred have been due to human carelessness, not to flaws in the underlying logic of the management system. The fact that the management system has worked so well must be emphasized to throw the proper light on the data described below which deal mainly with its inadequacies; the single statistic given above that PERC runs 300 students per day should constitute a significant achievement in automated management of CAI.

a) Students spend 24% of their instructional time either waiting for instruction or in changing an audio disc. This figure is just slightly below the figure from last year. Great pains have been taken to minimize the number of audio disk changes in this years curriculum; but they seem to have failed. Classroom observers report that students are still changing discs 2-3 times per 15 minute session.

One conclusion to be drawn is that the current management system does not allow for adequate control over an individual's session. Activities have been arranged so that activities which should follow one another are on the same disc; but since it is not possible to specify that certain activities be presented within the same session, the activities are not being presented in contiguous sequences.

b) Current data collected by the management system has logged 3976 total hours of instruction; however, data collected by the PLATO system shows our students have been signed on to the terminals for 4890 hours. Thus, PERC's data accounts for only 81% of the time logged by the system.

PERC's data does not include the time the management system takes to choose the next activity; it is currently not known how much of the discrepancy can be accounted for by time within the management system. Nevertheless, PERC can only account for 3010 hours of actual instruction out of 4890 hours counted by the PLATO system, which is only 62%; thus, the worst case may be that students spend up to 38% of their time at the terminal on non-instructional tasks.

c) According to an analysis of -percnotes- (the notes which are written by teachers to the PERC staff), the second greatest concern seems to be with problems with the management system (the first concern is with malfunctioning hardware). These concerns range from wanting to have greater control over what students get to complaining that individual students are unable to get lessons.

There is no doubt that teachers comment on the management system more than they do on lessons because they have the most contact with it, either through trying to use teacher options associated with it, or because students who cannot get any activities constitute more of a problem than students who have problems in activities. It is not clear that simply counting the number of comments is a valid indicator of teacher concerns; PERC hopes to validate the information gleaned from -percnotes- with a questionnaire to all teachers this Spring.

9) PERC has been Successfully Implemented in Classrooms.

Placing terminals directly in the classrooms has been a unique PERC experiment; only a few other projects (such as Montgomery County, Maryland) have tried to integrate CAI into the classroom. The goal for this year has been to spend a few days at the start of the year orientating each student to the terminal; coming back about a month later to show each child how to use the microfiche projector; but then staying out of the classrooms except to observe students working in activities. The first two parts have worked fairly well with most classrooms requiring no more than ten total days to get the students fully acquainted with the terminal.

The greatest concern of teachers (as seen in -percnotes-) is with hardware failures. Again, this is reasonable because hardware failures affect the teachers the most.

All types of hardware have failed; unfortunately PERC has no count on how many times each has failed. The teachers have complained most about the audio device; however, there have been very few complaints from the four classrooms using the new EIS audio machines.

Therefore, the third part of the goal--staying out of the classrooms except for observations--has not been attained; PERC observers have spent an inordinate amount of their time trying to keep up with the hardware needing repair. Another measure of this phenomenon is the paucity of reports about lessons coming back from PERC observers; whereas many ideas for improving lessons were passed on during the 1974-75 school year, very few have come in this year.

APPENDIX 5.2

PLATO Elementary Reading Curriculum Objectives

(Key to Structure Diagram)

1. GENERAL ENTERING REPERTORY

a. The student understands the dialect of English usually spoken on network television.

b. The student can attend to a cluster of stimuli similar to those of a television program for at least five minutes.

c. The student has visual acuity of at least 20/200 in the better eye, and the vision in that eye subtends an arc of at least 20 degrees.

d. The student has sufficient aural acuity that any hearing loss would not be technically described as greater than mild.

e. The student has sufficient intelligence and psychomotor maturity to carry out instructions of the following sort when the objects referred to are about the size of dimes and are contiguous with one another. "In front of you are pictures of a boy, a girl, a dog, a book. Touch the boy."

2. AUDITORY DISCRIMINATION OF PHONEMES

a. Given a group of words, two of which have the same initial, final or medial sound, the student indicates which two words have the specified similarity.

b. Given words which are phonemically different in either the initial, final, or medial position, the student indicates in which of those positions the words are different.

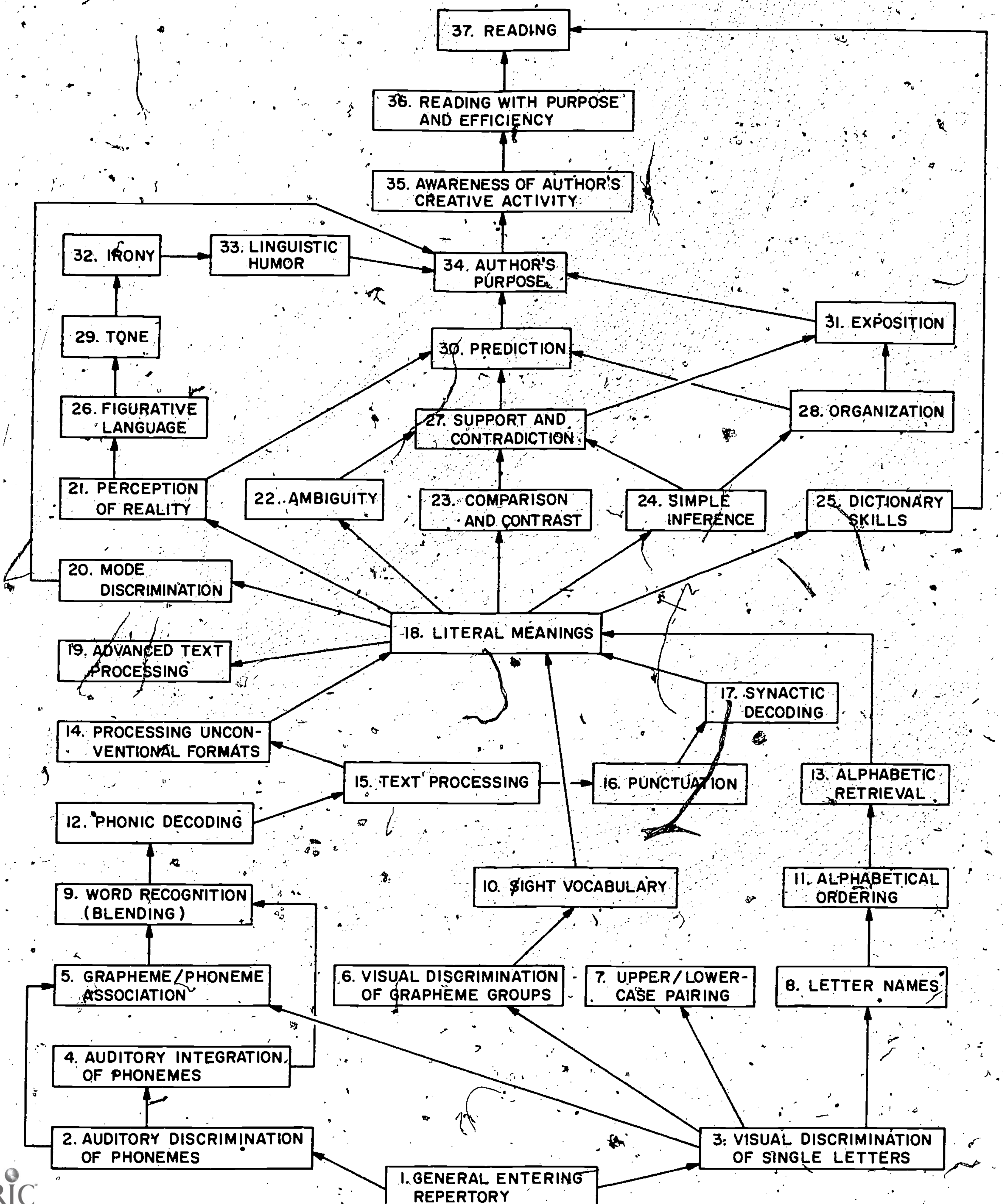
3. VISUAL DISCRIMINATION OF SINGLE LETTERS

Given a grapheme, the student indicates the identical grapheme in a field of other graphemes.

4. AUDITORY INTEGRATION OF PHONEMES

Presented aurally with a target word containing no more than three phonemes with short pauses between each phoneme, the student identifies a picture of the object represented by the target word in a field of other pictures, given that the target word is part of his oral vocabulary.

THE PLATO ELEMENTARY READING CURRICULUM
STRUCTURE OF OBJECTIVES



5. GRAPHEME-PHONEME ASSOCIATION

a. Given a grapheme, the student selects a picture of a word containing the sound the letter represents.

b. Given a phoneme in a morphemic environment, the student correctly chooses the grapheme which represents the phoneme.

6. VISUAL DISCRIMINATION OF GRAPHEME GROUPS

Given a sequence of graphemes, the student identifies the identical sequence in a group of other sequences.

7. UPPER AND LOWER CASE PAIRING

Given the upper case or lower case representation of a grapheme, the student locates its lower- or upper-case equivalent from a field of graphemes.

8. LETTER NAMES

Given any letter name orally and a selection of graphemes from which to choose, the student selects the appropriate grapheme.

9. WORD RECOGNITION (BLENDING)

Given a monosyllabic word composed of phonemes with a one-to-one phoneme-grapheme correspondence, the student blends the phonemes into a word, which, if it is in his oral vocabulary, he recognizes, whether he has spoken the blend aloud or not.

10. SIGHT VOCABULARY

a. The student recognizes at sight those monosyllabic and phonetically irregular words he encounters frequently in his reading.

b. The student recognizes at sight those phonetically regular words he encounters frequently in his reading.

11. ALPHABETICAL ORDERING

Given a selection of letters in random order, the student arranges the letters in correct alphabetical sequence.

12. PHONIC DECODING

Given the full set of middle-class, midwestern American English phonemes and rules governing their correspondence with the various graphemes, the student recognizes any word for which the rules exactly determine the pronunciation. In cases of ambiguous determination, but where the word is known orally to him and the written contest defines it, he recognizes it whether he has pronounced it aloud or not.

13. ALPHABETIC RETRIEVAL

Given an alphabetical list of information, the student retrieves any specified piece of information.

14. PROCESSING UNCONVENTIONAL FORMATS

Given written information in an unusual format but the correct directional sequencing of which is unambiguous, the student employs effective strategies for recovering the information.

15. TEXT PROCESSING

Given a selection written in an ordinary left-to-right, top-to-bottom format, the student processes the selection in this conventional order.

16. PUNCTUATION

The student demonstrates a knowledge of the function of punctuation sufficient to allow him to decode correctly sentences which, without punctuation, would be ambiguous.

17. SYNTACTIC DECODING

a. The student controls a sight-word vocabulary and phonetic decoding skills sufficient to allow him to interpret and comprehend the literal content of simple and compound sentences presented in written form.

b. The student correctly identifies as having identical meanings those sentences which are unambiguously repatterned statements of the same idea.

c. Given a series of sentences of arbitrary complexity but with clausal embeddings to a depth no greater than two and phrasal embeddings to a depth no greater than four, the student correctly restates the ideas of the sentence in his own words.

18. LITERAL MEANINGS

a. Given questions of the type, "Who did x?"; or "When and where did x happen?"; or "How did x feel?"; or "Why did x happen?" where such questions are answered explicitly in the passage, the student correctly answers the questions.

b. Given a selection in which the main idea is explicitly stated, the student correctly identifies the main idea.

19. ADVANCED TEXT PROCESSING

Asked to find specific information in a passage, the student employs text processing strategies appropriate to the purpose.

20. MODE DISCRIMINATION

Given a selection in which important information is presented by non-linguistic means, the student correctly discriminates between the pieces of information supplied by each mode of presentation.

21. PERCEPTION OF REALITY

a. The student distinguishes among the actual, possible and fanciful elements of a reading selection, identifying as actual those events commonly agreed to have happened, as possible those elements commonly agreed to be within reasonable expectation of happening, and as fanciful those elements which the current audience agrees are not possible. He distinguishes among these elements with the verbalized proviso that the distinctions are certainly based on incomplete knowledge and are, therefore, subject to change.

b. The student distinguishes between testable and untestable statements and forms opinions in such a manner that an opinion could include either or both types of statements.

22. AMBIGUITY

a. Given a selection in which the literal meanings of one or more passages are ambiguous, the student correctly identifies the passages and states their optional interpretations.

b. Given a sentence that is multiply ambiguous because of unknown words, the student recognizes the irresolvable nature of the ambiguities and requests enough additional information to resolve those ambiguities.

23. COMPARISON AND CONTRAST

Asked to find similarities and differences between two explicitly similar or different items in a single selection, the student does so.

24. SIMPLE INFERENCE

The student demonstrates an ability to draw correct and supportable inferences from a passage. These inferences will not contradict explicit information in the passage, and the student will cite or locate at least one explicit detail in the passage that supports his inference.

25. DICTIONARY SKILLS

a. Given a word whose meaning is not clear from context, the student consults a dictionary in an attempt to resolve the ambiguity.

b. Given a written word which he would recognize if spoken orally, the student correctly defines the word after having consulted a pronunciation key.

26. FIGURATIVE LANGUAGE

Given a selection containing figurative uses of language, the student correctly identifies the passages where such uses are employed and presents a plausible interpretation of the meaning of the figure and a plausible speculation for the author's employment of it. "Plausible" is taken to mean "not contradicted or made unlikely by the text."

27. SUPPORT AND CONTRADICTION

Given statements purportedly drawn from a passage he has just read, the student distinguishes between those which are explicit in the passage, those which are inferences supported by the passage, and those which contradict some portion of the passage.

28. ORGANIZATION

a. Given a selection in which temporal or spatial modes of organization are used, the student correctly identifies the mode or modes employed.

b. Given a selection in which the correct order of events in unambiguous but in which the order of presentation is not chronological, the student correctly rearranges the events chronologically.

29. TONE

The student correctly identifies the author's primary attitude toward his subject through supported reference to the tone of the author's writing.

30. PREDICTION

The student, having read enough of a story to gain information about the personalities of the characters and the nature of the central conflict, predicts an outcome for that story and defends his prediction through references to explicit detail and inference not contradicted by explicit information.

31. EXPOSITION

The student, having been acquainted with the thesis statement of an essay and having various pieces of evidence purportedly relevant to the thesis statement, proposes arguments which support the thesis statement and which are in turn supported by the evidence.

32. IRONY

Given a reading selection in which there is a discrepancy between the content of the material and its tone, the student recognizes such discrepancies.

33. LINGUISTIC HUMOR

Given a selection in which the literal meanings of one or more passages could be ambiguous outside of the context, the student correctly identifies the passages and state their alternative interpretations.

34. AUTHOR'S PURPOSE

Given a reading selection which purportedly has a single rhetorical purpose, the student identities some such rhetorical purpose that, when questioned, he can demonstrate the presence of by reference to explicit items in the text or by inference not contradicted by the text.

35. AWARENESS OF AUTHOR'S CREATIVE ACTIVITY

About written selections of all types the student verbalizes and defends by reference to examples the idea that written material is at best an abstraction from reality in which decisions concerning selection and abstraction are made by the author.

36. READING WITH PURPOSE AND EFFICIENCY

Given a selection to read, the student defines a realistic purpose in his reading of the selection and will employ skimming, scanning, and fixation strategies appropriate to his defined purpose.

37. READING

Reading is defined as understanding ideas presented in the written version of one's language and expressed in a manner appropriate to one's age and abilities.

APPENDIX 5.3

USING AUDIO WITH CAI LESSONS

Experiences of the PLATO Elementary Reading Project

Robert F. Yeager
Computer-based Education Research Laboratory
University of Illinois at Urbana-Champaign

For the past five years, the PLATO Elementary Reading Curriculum (PERC) Project has been developing activities primarily for use in first grade classrooms. In the 1975-1976 school year, twenty-five classrooms with over 750 students used PERC materials.

The typical classroom has two PLATO terminals in the classroom; each terminal is equipped with a touch panel, slide projector, and an audio unit. Students normally spend about fifteen minutes at the terminal; and they manipulate all of the hardware themselves; that is, they insert a microfiche into the slide projector, and they change records on the audio unit.

Random Access Audio

PERC uses a random access audio unit which is connected directly to the terminal. The command to play a message is sent from the computer, through the terminal, to the audio unit; the computer tells the audio where to start playing and how long that message will last. The computer retains control so that other processing can continue, such as displaying graphics on the terminal which coincide with what the audio is saying.

The audio record holds up to twenty-two minutes of recorded information. A single message can be as short as one-third second, or as long as forty-two seconds. Any message on the record can be accessed within one-half second after receiving the command from the computer. The records are made from large sheets of magnetic recording tape (the type used in tape recorders). Therefore, the audio unit can both play messages and record directly on to the record. Records can also be erased and used over and over again.

Using an audio unit that allows random access has been very important in developing PERC lessons. The alternative would have been to use serial audio (such as a cassette tape recorder) which would have required that lessons be organized so that all messages would be played in a predetermined order.

The most obvious advantage is that PERC has been able to produce some unique activities which allow each student to explore the activity in his own way; for example, one lesson puts a list of sight words on the screen and allows the students to hear any word by touching it.

Many PERC lessons are in such a stable condition now that they could almost be used with serial audio; all of the directions and items in the exercise are in an optimal sequence. But because of the random access capability PERC has been able to implement some powerful pedagogical strategies which would not have been possible with serial audio. For example, when a student misses a drill item, he not only is given immediate correction, but that same item will reappear in the drill as the third and fifth items after the error. Such strategies have been very successful with students. Thus, pedagogical strategies are not overruled by technological limitations.

An added bonus of random access audio has been that lessons have been easier to develop. When a lesson had to have an audio message changed or added, all that had to be done was to find an open area on the record and add the new message; with serial audio such changes would have been much more tedious.

Guidelines for Using Audio in Lessons

The PERC Project has developed four simple guidelines for using audio in lessons. But as obvious as these guidelines may appear, PERC has experimented with lessons in the past which follow completely opposite conventions. These guidelines have emerged as the ones that work best with our six-year-old population.

Guideline 1: Keep it short. The paradigmatic audio is, "Do it!," and PERC tries to translate all direction giving messages into something only slightly less cryptic. Elaborate explanations and rationales are eliminated; the audio must focus the student on the task and let him interact with the lesson as quickly as possible.

That guideline comes from years of watching children become distracted while a long audio message is recited to them. They "tune out" in the middle of the message and often miss the cue telling them what to do; then they either fail to respond or respond inappropriately.

Obviously not all children follow that pattern. Conventional children will put up with anything (perhaps these are the college-bound students?). But a larger number of six-year-olds view the terminal as a place where they can express themselves; and they do not have the patience to listen to the terminal express itself. PERC has had more success in aiming lessons at these expressive students than in trying to make the expressive students conform to conventional patterns.

It may seem as though PERC is shirking its duty to teach the expressive students to pay attention. Nevertheless PERC teachers report that one of the fringe benefits of using PERC lessons is that students develop better listening skills.

How long is a short audio message? The average PERC lesson runs about 2:50 minutes of which forty-seven seconds is audio. The average lesson has seventeen audio messages; each message lasts an average of 2.8 seconds. That means the student gets about three seconds of audio every ten seconds (based on data from 113,312 uses of PERC lessons in 1975-1976).

Eight of the seventeen messages are short messages less than 2.4 seconds; they are the drill items, such as single words, letters, or sounds. If the short messages are excluded so that only messages greater than 2.4 seconds are counted, the average audio message is still a brief 3.94 seconds.

Not only are audio messages kept short, but audio is usually faded in each lesson. There is usually a great deal of audio at the beginning of a lesson which the activity is being set up; but audio is quickly withdrawn once the student demonstrates that he understands the nature of the interaction. Audio feedback is severely limited with an emphasis being put on visual feedback. For example, the first few times a student makes a correct response, the audio might say, "good," and there would be an appropriate screen display; but then the audio is withdrawn and the student is reinforced by the visual display only.

Audio is limited because it intrudes on the pace of an interactive lesson. Students want to make the terminal "work," not listen to long explanations. A good lesson strives to make students active learners rather than passive listeners.

Guideline 2: Give the cue at the end of the message. For example, if the audio says, "Tap the word up to make the elevator go up," the student is likely to start responding as soon as he hears, "Tap the word up...." A better audio message would put the cue at the very end: "Make the elevator go up. Tap the word up."

A corollary to this rule is that complicated sentence structures should be avoided so that the cue is easily identifiable. Conditionals, for example, always cause problems; in a message like, "If you want the elevator to go up, then tap the word up," the if-then construction can complicate things sufficiently so that the student fails to comprehend what he is expected to do.

Guideline 3: The student must always be able to interrupt an audio message with a correct response. At one time PERC lessons would not accept any type of response until the directions on the audio were completed. But students often understand the nature of the task before the audio message is completely finished; and because they respond by simply touching the screen, students can enter several responses during the last second or two of an audio message. Students were observed to enter the correct response, get no feedback because the audio message was just finishing, and switch to an incorrect response just as the audio message ended.

The same problem occurs on remedial messages after an incorrect response. The student often recognizes the tone of the message and moves immediately to his second choice for an answer. While it may seem pedagogically desirable to explain to the student why he was wrong, in practice it does not work. People make explanations; machines do not. Machines are simply expected to perform in specified ways; so when the student enters the correct response, he expects that the machine will respond appropriately. If a student makes a correct response while an audio message is in progress, the audio message is immediately stopped, and the positive feedback is begun. This avoids the paradox of having the audio continue to tell the student to do something that he just did.

While an audio message is in progress, incorrect responses are ignored; the audio continues uninterrupted. This is really done out of necessity. If an incorrect answer was accepted before the audio had given the cue, the lesson would have to contain special remediation which would explain the task that was supposed to have been explained in the interrupted message; and that remedial message itself might have to be subject to interruption. In PERC's very early years, a few lessons were written that way. Some students quickly learned the joys of making the audio unit go crazy by repeating incorrect answers every second or two; this caused the audio to restart the same message over and over and over again.

The strategy of ignoring incorrect responses while audio is in progress is effective. It takes advantage of the students' strong desire to make the terminal "work." Receiving negative feedback is perceived by students as making the terminal work; and it is sufficiently reinforcing that students will persist in making the wrong response. But receiving no feedback at all discourages students from responding unless they are fairly certain that it is going to have an effect.

There is a glaring loophole in that strategy, however. If the student makes all possible responses while the audio is in progress, the incorrect responses will be ignored and the correct response will be rewarded. In fact, that happens very seldom. In the few cases where it did happen, the lesson was changed to stop it. One change that worked was to not display the answers until the audio was completed. Another method was to stop the audio, erase the screen, and restart the frame after telling the student that he had to start over because he has answered too soon; the success of this latter method has not been evaluated yet.

<u>Guideline 4</u>: Audio should be embedded in a context. Messages like, "Touch the word <u>boy</u>," were effective with some students but many students seemed to have difficulty comprehending what the audio said; they lacked the proper psychological set to handle the directions. Students sometimes verbalized what they thought they heard; their errors could be loosely grouped into four categories: 1) homonyms (boy-toy); 2) words conceptually linked (boy-runs); 3) words prompted by the sequencing in the exercise (if word one was "cat," and word two was "frog," the student might hear "dog" both because it sounds like "frog" and because of its relationship to "cat"); and 4) other answers on the screen (note that the students had to <u>read</u> the other answers).

There are two ways to provide context for an audio message: add more audio, or add a visual display. Sometimes the only thing that can be done is to add more audio despite the fact that this violates Guideline 1. But students are more likely to tap the word "up" if the audio cue is prefaced with a short statement like, "Make the elevator go up."

A better way of providing context is to add a visual display; if the audio says, "Tap the word boy," a picture of a boy can be shown on the screen.

Data was gathered during the 1975-1976 school year which tend to support the importance of a visual context. Records of errors were kept for forty auditory discrimination exercises; all forty exercises operate in the identical way except for the fantasy used for motivation; in a -t- exercise the student adds men to a tug-of-war team; in an -h- exercise, he adds horseshoes; etc. The task is for the student to decide whether or not a word presented by the audio begins with a specified sound; for example, does "telephone" start with /t/. This would seem to be a listening task; the student should not even have to understand the word in order to decide whether he hears a /t/ or not.

Twenty-five of the forty exercises presented the word via audio only; for the other fifteen exercises a picture was displayed on the screen while the audio said the word. After 44,268 trials, words given by audio alone had an error rate of 21%, words given by audio accompanied by a picture had an error rate of 12%.

Ninety-three of the words were used in both ways; they were used with pictures in some exercises, and without pictures in others. This was done primarily because many exercises were on the same record and they shared the same pool of words; hence the students heard the same recording of the word both with and without pictures. Approximately the same error rates held: for 17,572 trials, words without pictures had a 22% error rate; words with pictures had only a 12% rate.

Future Plans with Audio

There are two areas in which PERC would like to experiment with audio. First, students could record their voices on the record; this is essentially a language lab approach. The student could compare his voice to a pre-recorded model in order to decide when he is close enough; and a teacher could spot check her students' recordings to make sure they are performing adequately. This would be ny means be a substitute for the teacher listening to the students recite in the classroom; but it may be a way of giving students added practice in producing speech without putting a great deal of overhead on the teacher.

The second area would involve a much more radical change. Currently audio is delivered automatically throughout a lesson but PERC has now developed a few lessons in which the student has to request the audio either by touching someplace on the screen or by pressing a key. Thus the learner gains control over the flow of information that is directed at him. He can be somewhat selective about what informatin he wishes to receive; for example, students who have seen a few of those forty auditory discrimination exercises do not usually need even the minimal directions given at the beginning of each exercise; with "learner-controlled" audio they could skip past the directions.

The few lessons that have been developed with "learner-controlled" audio have been in a very narrow range. Various types of lessons will have to be developed before the usefulness of this strategy can be evaluated.

Summary

PERC follows the principle that the best audio is the least audio. That principle is put into practice by, 1) keeping messages as short as possible; 2) making cues easily identifiable; 3) allowing students to interrupt audio; and 4) providing minimal context to aid understanding. And it would be extended even further if learner-controlled audio were implemented.

The guidelines described have been found to be affective with six-year-olds. But they are probably somewhat valid for all age groups although older students may put up with slightly longer audio messages, and may require fewer prompts.

Acknowledgements

The PLATO Elementary Reading Project is supported in part by the National Science Foundation (US NSF C-723) and the University of Illinois. I wish to thank the many CERL staff members who have contributed to the ideas discussed here; and Sibyl Pellum for manuscript preparation.

APPENDIX 6.2.1

ACCOUNTANCY LESSON APPLICABILITY

By actual uses except where otherwise noted. Based upon the Fall 1975 usages.

	Author	Time	101	102	Cost	Ac Clerk	Adult Ed	Learning Lab
(1) Introduction to PLATO IV	McK	30	x	x	x	x	x	x
Comments and Bulletin Board	McK	2	x	x	x	x	x	x
Accrual Concepts	McK	20	x	x	x	x	x	x
Classification of Accounts	McK Len	20	x				x	x
Classification and Normal Balances	McK Len	20	x				x	x
Changes in Balance Sheet Equations	McK	40	x				x	x
Journalizing	McK	60	x				x	x
Income Statement	McK	45	x					x
Journalizing - Service and Merchandising Firms	McK Len	30	x				x	
Journalizing - Service Firm Only	McK Len	30	x				x	x
Closing Entries	McK Len	40	x				x	x
General Journal, Ledger	McK Len	und	x					x
Adjusting Entries	McK Len	45	x			x	x	x
Adjusting Entries II	McK	60	x			x	x	x
Worksheets	McK Len	45	x			x	x	x
Inventories	McK	30	x	x	x	x	x	x
Special Journals	McK Len	10	x			x	x	x
Terms of Sale	McK Len	45	x			x	x	x
Inventory Methods	McK	45	x	x	x	x	x	x
Temporary Investments	McK	60	x	x		x		x

Accountancy Lesson Applicability

(continued)

	Author	Time	101	102	Cost	Ac Clerk	Adult Ed	Learning Lab
Bank Reconciliations	McK Len	50	x			x	x	x
Accounts Receivable	McK	und	x			x	x	x
Notes and Interest	McK Len	60	x			x	x	x
(1) Long Term Liabilities (Straight Line)	McK	30		x				x
(1) Long Term Investments (Straight Line)	McK	60		x				x
Fixed Assets I	McK	60	x	x	x	x	x	x
Fixed Assets II	McK	45		x	x			x
Long Term Liabilities (Effective Rate)	McK	60		x		x	x	x
Accounting for Stockholder's Equity	McK	60		x	x	x	x	x
Long Term Investment in Bonds (Effective Rate)	McK	60		x				x
Funds Flow	McK	60	x	x	x	x	x	x
Funds Statement	McK	60		x	x			x
Introduction to Cost Accounting	McK et al	45		x		x		x
Break-Even Analysis	McK et al	45	x	x		x		x
Cost Classification	McK et al	15		x				x
Process Costing	McK et al	90		x	x			x
Job Order Costing	McK et al	60		x	x			x
Standard Costing I	McK et al	15		x	x	x		x
Standard Costing II	McK et al	45		x	x	x		x
Operational and Production Budgeting	McK	30		x	x			x
Budgeting for Control	McK	15		x		x		x
Non-Manufacturing Costs	McK	60		x				x

Accountancy Lesson Applicability

(continued)

	Author	Time	101	102	Cost	Ac Clerk	Adult Ed	Learning Lab
Financing (Cash Budgeting)	McK	20		x				x
Incremental Analysis	McK	20		x		x		x
Compound Interest	McK	und		x		x		x
Capital Budgeting	McK	45		x		x		x
Cost vs. Equity	McK	30		x				x
Partnerships	Trent	30		x	x	x		

Abbreviations: Len : Thomas Lenehen, Assistant Professor, Wright College
McK : James McKeown, Associate Professor, University of Illinois
Trent: George Trent, Associate Professor, Wright College
et al: acknowledges contributions of other faculty and graduate students
und : undetermined

Notes: (1) Applicability of "Long Term Liabilities (Straight Line)" and "Long Term Investments (Straight Line)" is estimated rather than actual.

(2) Times in minutes are from the Accountancy Index (1976). Since experience shows that lessons usually require longer to complete than estimates indicate, the larger estimate has been chosen when the Index indicates an estimated range (e.g., "Accrual Concepts," 15 - 20 minutes). Even so, estimates here should be considered conservative.

(3) Scattered and occasional use of lessons in courses disregarded in assessing applicability. Only consistent usage was acknowledged in determining applicability.

(4) Two lessons "Dependent Exemptions" by Costabile and "Payroll and Payroll Taxes" by Weaver have not been released for general use and are not included here.

APPENDIX 6.2.2

CORRELATION OF PLATO LESSONS WITH CLASSROOM MATERIALS

School #5

Business 101, PLATO Lesson Sequence

Text Chapter	Title of PLATO Lesson
Chapter 1	Introduction to PLATO IV Changes in Balance Sheet Equations
Chapter 2	Classification and Normal Balances Journalizing Journalizing - Service Firm Only
Chapter 3	Adjusting Entries Worksheets Closing Entries
Chapters 4 & 5	Journalizing - Service and Merchandising Firms Special Journals Terms of Sale
Chapter 6	Closing Entries General Journal, Ledger
Chapter 7	Notes and Interest Accounts Receivable
Chapter 9	Adjusting Entries II
Chapter 11	Bank Reconciliations

<u>Text to be used in conjunction with PLATO</u>

<u>Accounting Principles</u>, eleventh edition, by Niswonger and Fess (Southwestern Publishing Company)

(continued)

CORRELATION OF PLATO LESSONS WITH CLASSROOM MATERIALS

School #4

Business 101, PLATO Lesson Sequence

Text Chapter	Title of PLATO Lesson
Chapter 1	Introduction to PLATO IV Changes in Balance Sheet Equations
Chapter 2	Classification and Normal Balances Journalizing Journalizing - Service Firm Only
Chapter 3	Adjusting Entries Worksheets Closing Entries (Parts 1 and 2)
Chapter 4	Terms of Sale
Chapter 5	Special Journals
Chapter 6	Journalizing - Service and Merchandising Firms (Part 3) Inventories (Parts 2 and 3)
Chapter 7	Notes and Interest Accounts Receivable
Chapter 8	Inventory Methods
Chapter 9	Accrual Concepts Income Statement
Chapter 10	Fixed Assets I Fixed Assets II

Text to be used in conjunction with PLATO

Accounting Principles, eleventh edition, by Niswonger and Fess (Southwestern Publishing Company)

(continued)

CORRELATION OF PLATO LESSONS WITH CLASSROOM MATERIALS

School #2

Accounting Clerk, PLATO Lesson Sequence

Comment and Bulletin Board
Introduction to PLATO IV
Classification of Accounts
Classification and Normal Balances
Changes in Balance Sheet Equations
Journalizing
Worksheets
Special Journals
Terms of Sale
Journalizing - Service and Merchandising Firms
Closing Entries
Income Statement
Accrual Concepts
Notes and Interest
Accounts Receivable
Adjusting Entries
Inventories
Inventory Methods
Adjusting Entries II
Fixed Assets I
Fixed Assets II
Bank Reconciliations
Accounting for Stockholder's Equity
Long Term Liabilities (Effective Rate)
Temporary Investments
Long Term Investments (Effective Rate)

<u>Text to be used in conjunction with PLATO</u>

<u>Accounting Principles</u>, eleventh edition, by Niswonger and Fess
(Southwestern Publishing Company)

(continued)

CORRELATION OF PLATO LESSONS WITH CLASSROOM MATERIALS

School #1

Accounting 102, PLATO Lesson Sequence

Text Chapter	Title of PLATO Lesson
Chapter 15	Introduction to PLATO IV Partnerships
Chapters 16 and 17	Accounting for Stockholder's Equity Financing (Cash Budgeting) (Part 3 only)
Chapter 18	Long Term Liabilities (Effective Rate) Long Term Investments (Effective Rate)
Chapter 19	none available
Chapter 20	Introduction to Cost Accounting Cost Classification Process Costing
Chapter 21	Job Order Costing
Chapter 22	Standard Costing I Standard Costing II
Chapter 24	Non-Manufacturing Costs
Chapter 25	Capital Budgeting Break Even Analysis Operational and Production Budgeting (Part 1)
Chapter 26	Funds Flow Funds Statement
Chapter 27	none available
Chapter 28	Operational Production Budgeting (Part 2)

(continued)

Correlation of PLATO Lessons with Classroom Materials

School #1

Note: Only one instructor used PLATO as an integral part of the Accounting 102 class. Other instructors of Accounting 101 and 102 assigned their students to Learning Lab, where individual sequences of lessons were created for each students.

Text to be used in conjunction with PLATO

Accounting Principles, eleventh edition, by Niswonger and Fess (Southwestern Publishing Company)

APPENDIX 6.2.3

PLATO ACCOUNTANCY COURSE USAGE BY INSTRUCTOR

	Summer 74	Fall 74	Spring 75	Summer 75	Fall 75	Spring 76
School #1						
Instructor 8					101 and learning lab	101 and learning lab
Instructor 8		3 sections 101 learning lab	101, 102 learning lab	learning lab	102 learning lab	102 learning lab
Instructor A						1 section 102
School #2						
Instructor B			Acct Clerk	Acct Clerk		Acct Clerk
Instructor 1			Acct Clerk		Acct Clerk (E.S.L.)	Acct Clerk (E.S.L.)
School #3						
Instructor 6			1 section 101		1 section 101	1 section 100 1 section 101
Instructor I						1 section 101
School #4						
Instructor A		2 sections 101	1 section 101 1 lab group	release time for curriculum coordination with PLATO	1 section 101	1 intermediate lab group, release time for lesson development

PLATO Accountancy Course Usage by Instructor

(continued)

	Summer 74	Fall 74	Spring 75	Summer 75	Fall 75	Spring 76
School #5						
Instructor 3		2 sections 101	1 section 101 1 section 102		3 sections 103 1 section 101	1 section 101
Instructor C	1 section 101	no longer employed				
Instructor D	1 section 101	2 sections 101	2 sections 101			2 sections 101
Instructor 7		2 sections 101	2 sections 102	1 section 101 1 section 102	Cost Acct 1 section 101 1 section 102	Cost Acct 1 section 101 release time for lesson development
Instructor 5		1 section 100	1 section 100		1 section 101 1 section 402	1 section 101 2 sections 102
Instructor E			1 section 101 1 section 102	retired		
Instructor F	1 section 101 1 section 141	used as control				
Instructor G		2 sections 101	2 sections 101 1 section 102 Bus Math	1 section 101 1 section 102 Bus Math	on leave	
Instructor 2	2 sections 101	3 sections 101		1 section 102	Adult Ed. 2 sections 102	
Instructor H		Cost Acct				Cost Acct

Note: Instructor numbers correspond to accountancy identification numbers of the Users' Report, March 1976. Instructors identified by letter did not use PLATO during Fall 1975 and were thus not included in the Users' Report.

APPENDIX 6.2.4

STUDENT USAGE OF ACCOUNTANCY LESSONS
at the Community College

June 1974 - May 1976

	Summer 74		Fall 74		Spring 75		Summer 75		Fall 75		Spring 76		Total	
	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs	#St	#Hrs
School #1			73	565	63	455	24	87	182	1,073	97	381	439	2,561
School #2					33	198	25	200	10	49	32	230	100	677
School #3					35	144	0	0	35	298	77	349	147	791
School #4			82	492	35	94	0	0	35	411	20	101	172	1,098
School #5	141	291	531	2,177	314	1,342	144	672	335	1,237	268	1,208	1,733	6,927
TOTAL	141	291	686	3,234	480	2,233	193	959	597	3,068	494	2,269	2,591	12,054

APPENDIX 6.3.1

BIOLOGY USER PARTICIPATION

Inst	Fall 1974					Spring 1975					Fall 1975					Spring 1976				
#	101	111	102	112	other	101	111	102	112	other	101	111	102	112	other	101	111	102	112	other
1								XX	X		XX			X				XX	X	
2						XX	X				XX						X			X
3							X				XX	X				XX	X			
Δ 4		X					X				X						X			
5	XX		X					XX			XX							X		
6								XX					X						X	X
Δ 7		X				X				X			X						X	
OΔ 8		X	XX						X				XX					XX		
9								XX	X				X	X		XX			X	
10				xxO					xΔ			X		X						
11						X	X					X								
OΔ12		X			X				X			X			X		X			X
13									X			X							X	
14					O		xΔ					XX					XX			
15		X							X			X							X	
16												X			X		X			XX
17					O		xΔ					X					X			

Inst. # refers to Fall 1975 Users Report
O = participation in extension course -- users
Δ = participation in extension course -- authors
x = instructor taught one section
xx = instructor taught two sections

Biology User Participation
(continued)

Inst #	Fall 1974					Spring 1975					Fall 1975					Spring 1976				
	101	111	102	112	other	101	111	102	112	other	101	111	102	112	other	101	111	102	112	other
O 18	x		x	x		x	x		x			x		x			xΔ	x		
Δ19														x					x	
20										O					xx					xx
21										xx					xx					xx
A																xx				
B																	xO			
C																	x		x	
D																	xx			
(14)E						x														x
(19)F						x			x											
(8)G							x													
(10)H										x										

Inst # refers to Fall 1975 Users Report
Letters indicate users not included in Report
# in parentheses refers to case study in Spring 1975 Users Report
O = participation in extension course -- users
Δ = participation in extension course -- authors
x = instructor taught one section
xx = instructor taught two sections

	Fall 1974	Spring 1975	Fall 1975	Spring 1976
Total # Instructors	8	22	21	24
Total # Courses	16	36	36	43

APPENDIX 6.3.2

SOURCES OF LESSON DEVELOPMENT

BIOLOGY 101 AND 111

	CCC[1]	UIUC[2]				UICC[3]	MISC[4]
		Bio 100 101	Bot 100	NSF	Misc		
1. Tools Used in Biology				F74			
Review of Logs and Exponents					F75		
Exponential Growth Formulas					F75		
Graphing Exponential Cell Growth Data					F75		
A Tool: The Spectrophotometer			F75				
Experimental Technique			F75				
Life in a Microcosm			F75				
Serial Dilutions						F75	
2. Simple Chemistry I	F74						
Simple Chemistry II	F74						
Chemistry for Biology Students	F76						
3. The Ultrastructural Concept	F74 F76[5]						
Cells -- Structure and Function	F74						
Diffusion and Osmosis		F74					
Introduction to Water Relations			F75				
Water Relations Laboratory			F75				
Surface Area/Volume in Living Systems		Sp75					
Cell Growth					F75		
5. DNA and Protein Synthesis				F74			
DNA, RNA, and Protein Synthesis		F74					
6. Enzyme Experiments				F74 Sp75			
Essentials of Photosynthesis		F74					
Photosynthesis (Haney)			F74				
Experiments in Photosynthesis			F74				
ATP, Anaerobic, and Aerobic Respiration		F74					
Electron Transport Chain		F74					
Measuring the Level of Life		F74					
Respiration and Enzymes			F75				

[1]CCC = City Colleges of Chicago
[2]UIUC = University of Illinois at Urbana-Champaign
[3]UICC = University of Illinois at Chicago Circle
[4]MISC = other locations
[5]The earlier date indicates first version, later date the revision.

Sources of Lesson Development

Biology 101 and 111

(continued)

	CCC	UIUC Bio 100 101	UIUC Bot 100	UIUC NSF	UIUC Misc	UICC	MISC
Experiments in Respiration			F75				
Green Machine I (Photosynthetic Parts)	F74 F76			1			
Green Machine II (Process)	F76			1			
10. Seed Germination			F74				
Plant Growth			F74				
Plant Responses and Apical Dominance			F74				
Flowering and Photoperiod			F74				
Fruiting and Leaf Senescence			F74				
Enzyme-Hormone Interactions			F74				
Organization of the Higher Plant			F75				
11. Plant Pathology			F75				
12. Use of Taxonomic Keys						Sp75	
Plant Taxonomy			F75				
Tree Identification Quiz			F75				
13. ADH and Water Balance in Humans		F74					
Neuron Structure and Function		F74					
Human Digestive System				F75[1]			
The Heart	F75						
Cardiac Cycle	F74 F75						
Heart Rate Regulatory Mechanisms	F74 F75						
Mechanics of Breathing	F74 F75						
Elementary Psycho-physiology of Audition							F75
Central Nervous System	F76			1			
14. Physiological Basis of Learning		F75					
Simple Animal Behavior -- Klinokinesis						F74	
Social Behavior of Birds						F74	
Classical Imprinting in Fowl	—	—	—	—	—	F74 ?	
TOTAL NUMBER OF LESSONS AVAILABLE = 55	12	10	19	4	4	5	1

[1]Community College Project involvement

SOURCES OF LESSON DEVELOPMENT

BIOLOGY 102 AND 112

(continued)

	CCC[1]	UIUC[2]				UICC[3]	MISC[4]
		Bio 100 101	Bot 100	NSF	Misc		
4. Mitotic Cell Division	Sp75						
Mitosis	F74 F75[5]						
Meiosis (Arsenty)		Sp75					
Meiosis (Porch)	F74 F76						
Embryology	F75						
Plant Life Cycles			F75				
Hormonal Control of the Menstrual Cycle	Sp75			[6]			
7. Vocabulary Drills for Genetics -- Part I	F75						
Vocabulary Drills for Genetics -- Part II	F75						
Elementary Probability and Mendel's Laws				F74			
Blood Typing	F74 Sp75						
Genetics and Heredity			Sp75				
Drosophila Genetics				F74			
Gene Mapping in Diploid Organisms						F74	
Plant Genetics Problems			F74				
8. Natural Selection						F74	
Natural Selection Experiment						F74 F76	
Comparative Serology						F74	
Induced Mutations Experiment			Sp75				
Genetic Drift						F74 F76	
9. Biogeochemical Cycles				F74			
Energy Relationships in Biological Systems				F74			
Predator-Prey Relationships				F74			
Buffalo -- Animal Population Experiment					F74		
Population Dynamics		F74					
Populations Laboratory Using *E. coli*			Sp75				

[1]CCC = City Colleges of Chicago
[2]UIUC = University of Illinois at Urbana-Champaign
[3]UICC = University of Illinois at Chicago Circle
[4]MISC = other locations
[5]The earlier date indicates first version, later date the revision.
[6]Community College Project involvement

Sources of Lesson Development

Biology 102 and 112

(continued)

	CCC	UIUC				UICC	MISC
		Bio 100 101	Bot 100	NSF	Misc		
Stationary Phase of Cell Growth					F75		
Lag Phase of Cell Growth					F75		
Death Phase of Cell Growth					F75		
Population Genetics -- Demonstration of Inbreeding					F75		
Population Genetics -- Hardy-Weinberg					F75		
Population Genetics -- Quantitative					F75		
TOTAL NUMBER OF LESSONS AVAILABLE = 32	8	2	5	5	7	5	0

APPENDIX 6.3.3

BIOLOGY LESSON AVAILABILITY

BIOLOGY 101 AND 111

	F74	Sp75	F75	Sp76	Projected Additions
*1. Tools Used in Biology	x	x	x	x	
Review of Logs and Exponents		on request	x	x	
Exponential Growth Formulas		on request	x	x	
Graphing Exponential Cell Growth Data		on request	x	x	
A Tool: The Spectrophotometer			x	x	
Experimental Technique			x	x	
Life in a Microcosm			x	x	
Serial Dilutions			x	x	
2. Simple Chemistry I	x	x	on request	on request	
Simple Chemistry II	x	x	on request	on request	
Chemistry for Biology Students					x
3. The Ultrastructural Concept	+	+	+	x	R
Cells -- Structure and Function	x	x	x	x	
Diffusion and Osmosis	x	x	x	x	
Introduction to Water Relations			x	x	
Water Relations Laboratory			x	x	
Surface Area/Volume in Living Systems		x	x	x	
Cell Growth		on request	x	x	
5. DNA and Protein Synthesis	x	x	x	x	
DNA, RNA, and Protein Synthesis	x	x	x	x	
6. Enzyme Experiments	x	R	R	R	
Essentials of Photosynthesis	x	x	x	x	
Photosynthesis]	x	x	x	x	
Experiments in Photosynthesis]			x	x	
ATP, Anaerobic and Aerobic Respiration	x	x	x	x	
Electron Transport Chain	x	x	x	x	
Measuring the Level of Life	x	x	x	x	
Respiration and Enzymes			x	x	
Experiments in Respiration			x	x	
Green Machine I (Photosynthetic Parts)					R
Green Machine II (Process)					x

*Lessons included in biology catalog; numbers refer to position in the index.
\+ Lesson available but without microfiche
R Revised version in use

Biology Lesson Availability

Biology 101 and 111

(continued)

		F74	Sp75	F75	Sp76	Projected Additions
10.	Seed Germination	x	x	x	x	
	Plant Growth	x	x	x	x	
	Plant Responses and Apical Dominance	x	x	x	x	
	Flowering and Photoperiod	x	x	x	x	
	Fruiting and Leaf Senescence	x	x	x	x	
	Enzyme-Hormone Interactions	x	x	x	x	
	Organization of the Higher Plant			+	x	
11.	Plant Pathology			+	x	
12.	Use of Taxonomic Keys		x	x	x	
	Plant Taxonomy			+	x	
	Tree Identification Quiz			+	x	
13.	ADH and Water Balance in Humans	x	x	x	x	
	Neuron Structure and Function	x	x	x	x	
	Human Digestive System			x	x	
	The Heart			x	x	
	Cardiac Cycle	x	x	R	R	
	Heart Rate Regulatory Mechanisms	x	x	R	R	
	The Mechanics of Breathing	x	x	R	R	
	Elementary Psycho-physiology of Audition			x	x	
	Central Nervous System					x
14.	Physiological Basis of Learning			x	x	
	Simple Animal Behavior -- Klinokinesis	x	x	x	x	
	Social Behavior of Birds	x	x	x	x	
	Classical Imprinting in Fowl		x			
	TOTAL NUMBER OF LESSONS AVAILABLE	27	30	48	48	52

\+ Lesson available but without microfiche
R Revised version in use

BIOLOGY LESSON AVAILABILITY

BIOLOGY 102 AND 112

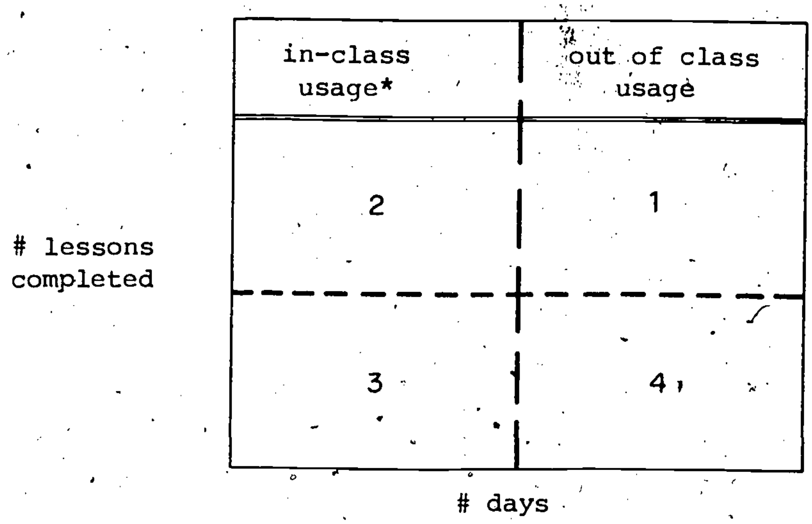
(continued)

		F74	Sp75	F75	Sp76	Projected Additions
*4.	Mitotic Cell Division		x	x	x	
	Mitosis	x	x	R	R	
	Meiosis (Arsenty)		x	x	x	
	Meiosis (Porch)	x	x	on request	on request	R
	Embryology			x	x	
	Plant Life Cycles			+	x	
	Hormonal Control of the Menstrual Cycle		x	x	x	
7.	Vocabulary Drills for Genetics -- Part I			x	x	
	Vocabulary Drills for Genetics -- Part II			x	x	
	Elementary Probability and Mendel's Laws	x	x	x	x	
	Blood Typing	x	R	R	R	
	Genetics and Heredity		x	x	x	
	Drosophila Genetics	x	x	x	x	
	Gene Mapping in Diploid Organisms	x	x	x	x	
	Plant Genetics Problems	x	x	x	x	
8.	Natural Selection	x	x	x	x	
	Natural Selection Experiment	x	x	x	x	
	Comparative Serology	x	x	x	x	
	Induced Mutations Experiment		x	x	x	
	Genetic Drift	x	x			R
9.	Biogeochemical Cycles	x	x	x	x	
	Energy Relationships in Biological Systems	x	x	x	x	
	Predator-Prey Relationships	x	x	x	x	
	Buffalo -- Animal Population Experiment	x	x	x	x	
	Population Dynamics	x	x	x	x	
	Populations Laboratory Using *E. coli*		x	x	x	
	Stationary Phase of Cell Growth		on request	x	x	
	Lag Phase of Cell Growth		on request	x	x	
	Death Phase of Cell Growth		on request	x	x	
	Population Genetics -- Demonstration of Inbreeding			x	x	
	Population Genetics -- Hardy-Weinberg			x	x	
	Population Genetics -- Quantitative			x	x	
	TOTAL NUMBER OF LESSONS AVAILABLE	16	22	30	30	32

*Lessons included in biology catalog; numbers refer to position in the index.
\+ Lesson available but without microfiche
R Revised version in use

APPENDIX 6.3.4

SAMPLE SCATTER PLOTS



*This could include some outside usage if student had to make up a missed session.

– – – – – – – – = 50% of lessons available to the students

—— —— —— = # of scheduled sessions, time reserved for class

Quadrant #1: Students used extra sessions on their own time to complete more than 50% of the lessons.

Possible Explanations: lessons assigned, students highly motivated, extra credit, attendance graded.

Quadrant #2: Students were able to complete over half the lessons during scheduled times.

Possible Explanations: lessons too easy, too few made available, students very well-prepared.

Quadrant #3: Students did not complete lessons but did not utilize time allowed.

Possible Explanations: lessons were not assigned, used for enrichment, students not well-prepared.

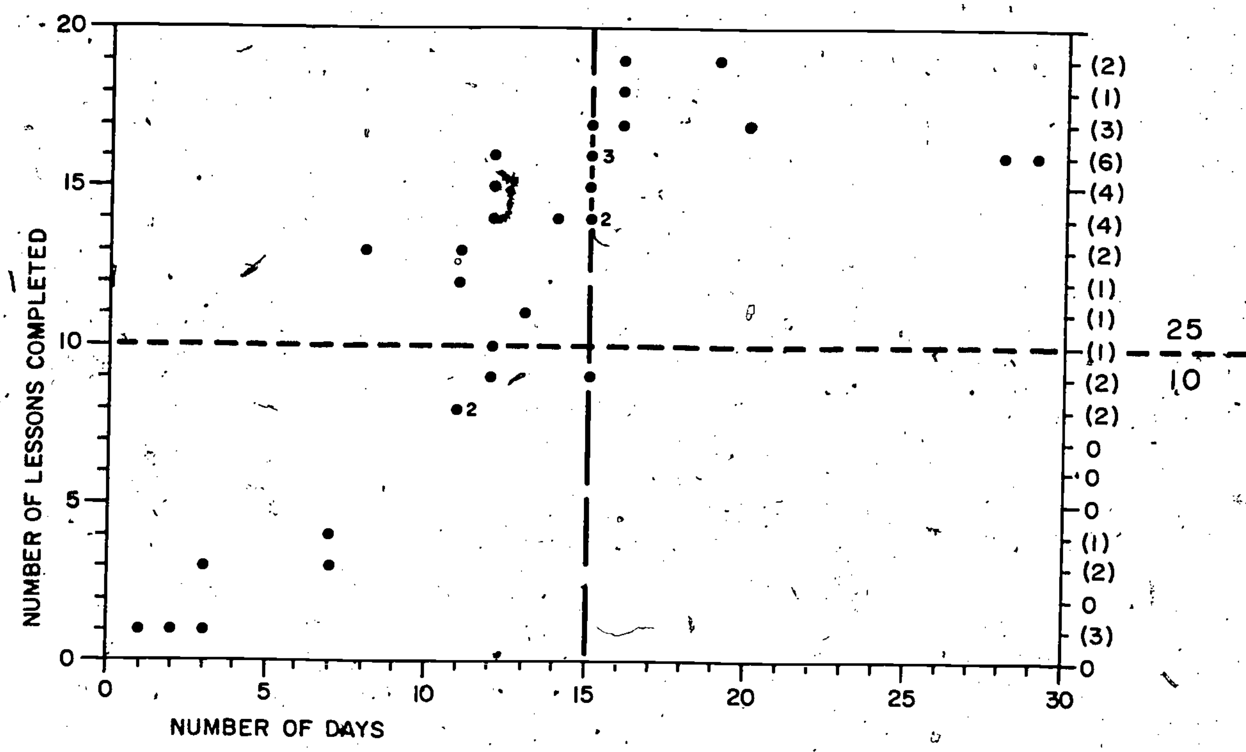
Sample Scatter Plots

(continued)

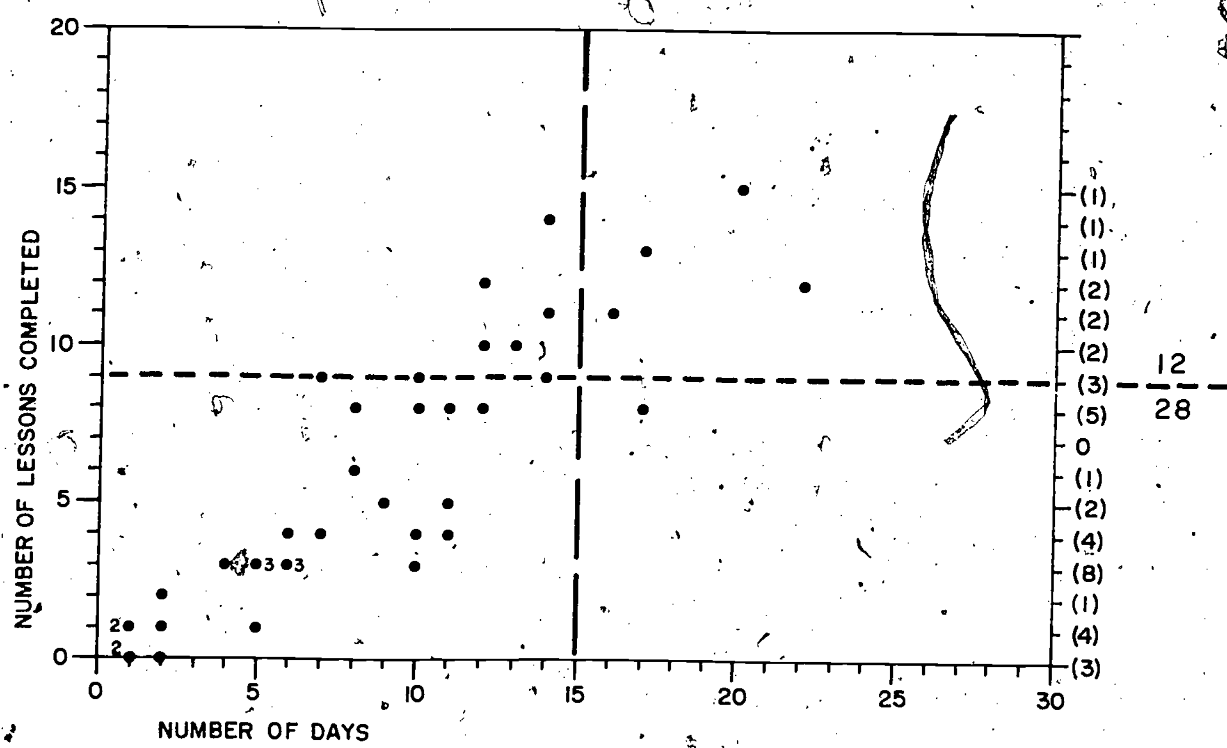
Quadrant #4: Students required extra sessions and still were unable to complete lessons.

Possible Explanations: lessons too hard, too many lessons available, high student motivation.

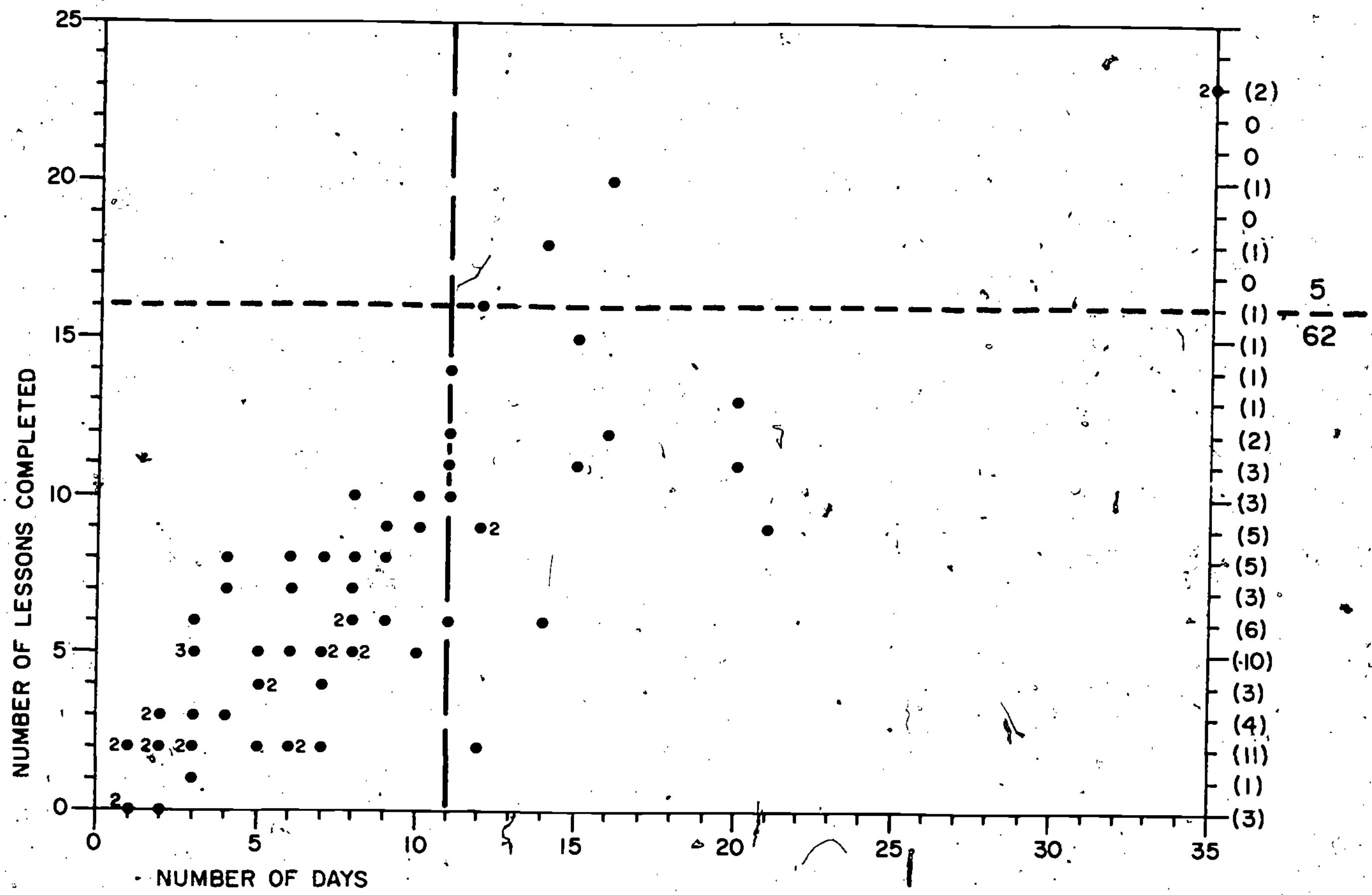
If Quadrants #1 and #4 are large it implies that the teacher relies mainly on independent usage. Large Quadrants #2 and #3 indicate that the teacher intends for usage to occur in scheduled sessions.



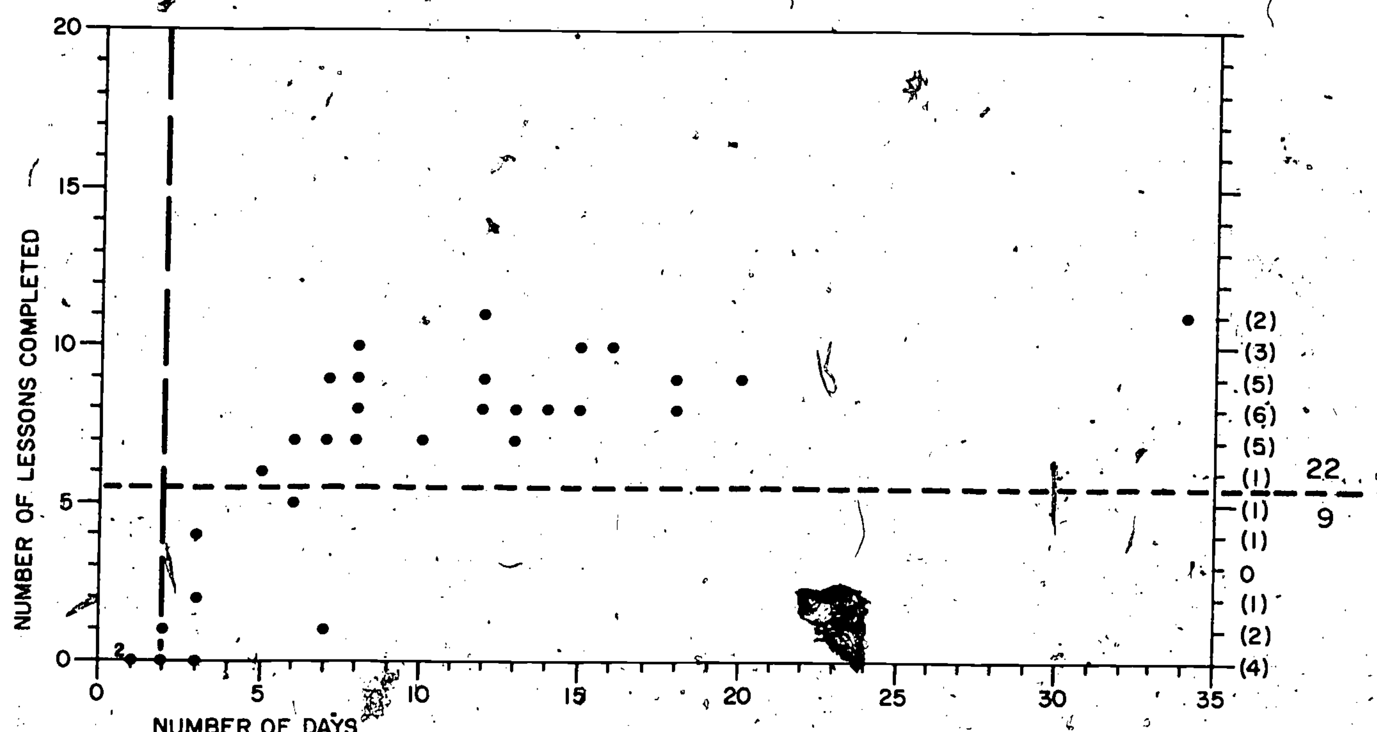
Biology 111 Instructor #B 35 students 20 lessons available



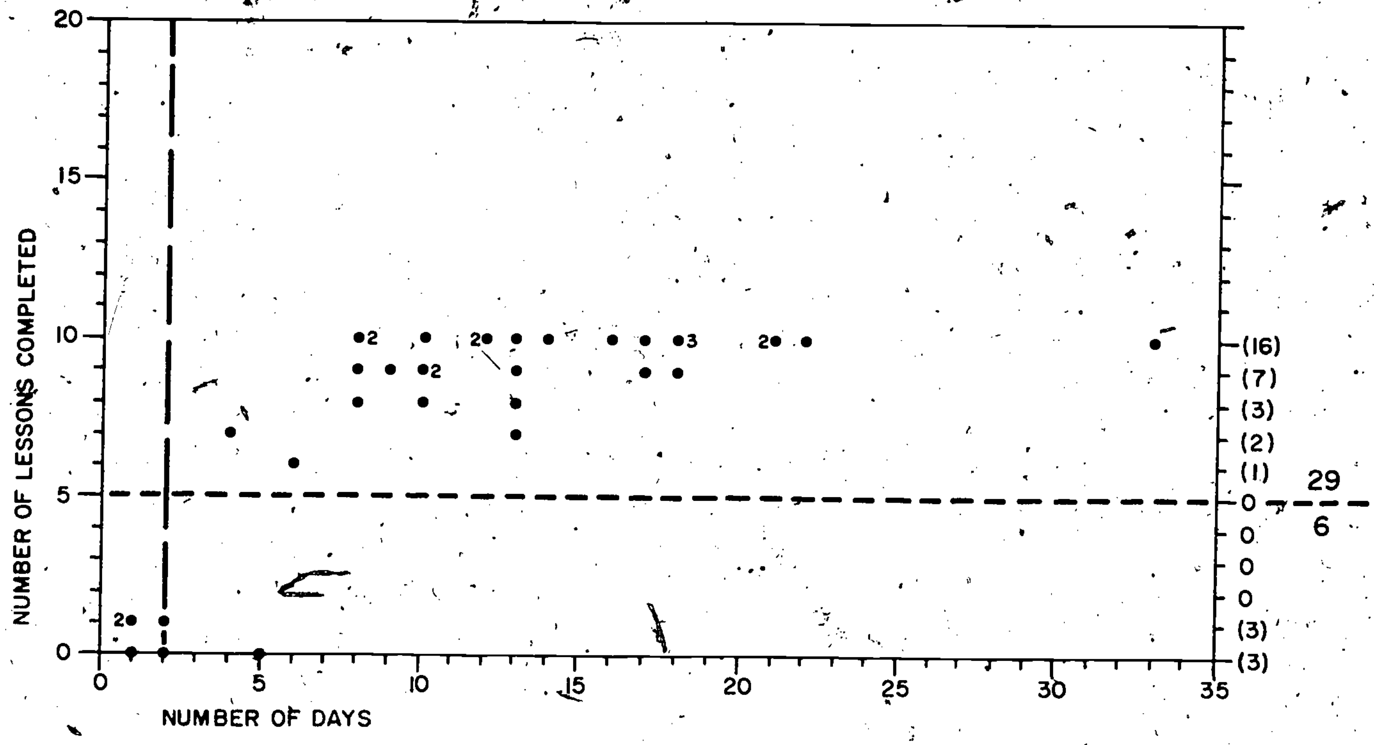
Biology 111 Instructor #2 40 students 18 lessons available



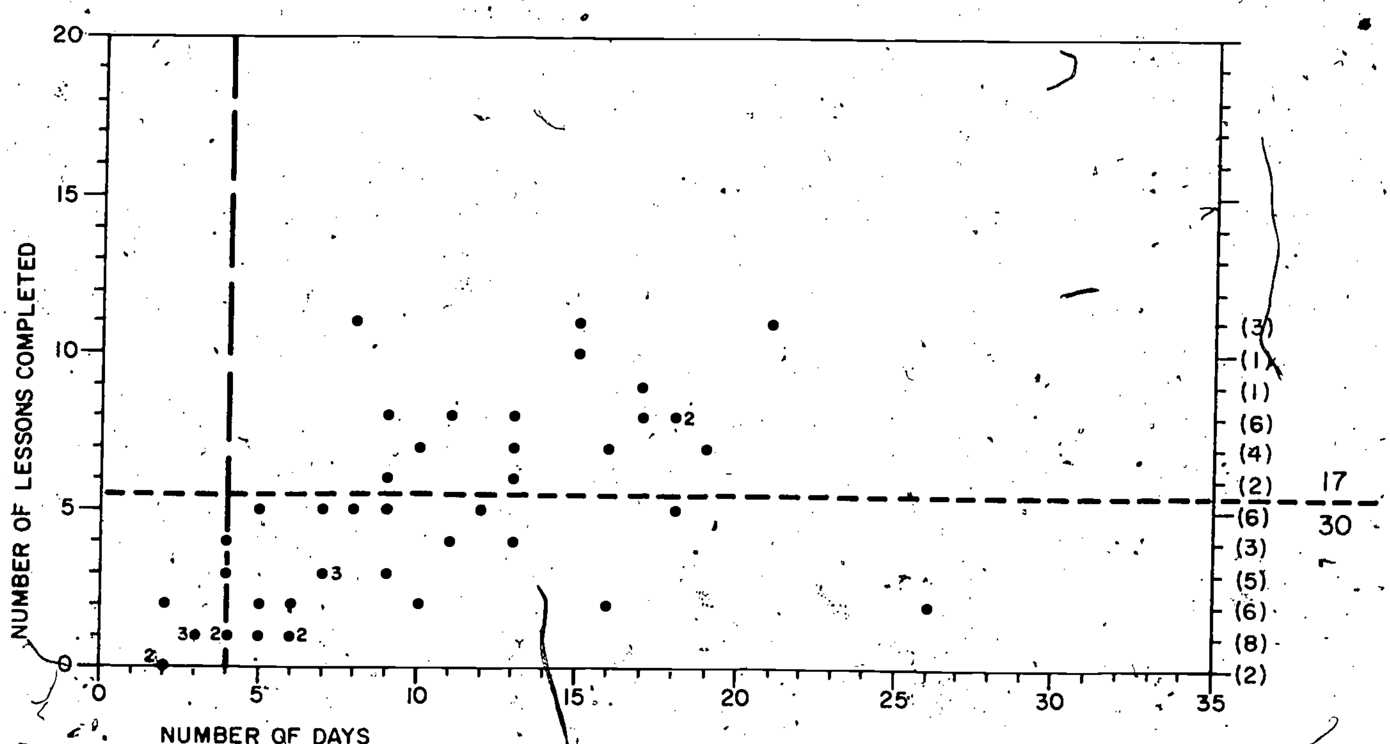
Biology 101 (2 sections) Instructor #3 67 students 32 lessons available



Biology 102 Instructor #1 31 students 11 lessons available



Biology 112 Instructor #1 35 students 10 lessons available



Biology 102 (2 sections) Instructor #8 47 students 11 lessons available

APPENDIX 6.3.5

STATISTICAL TEST ON COURSE USAGE DATA

Factorial fixed affects of analysis of variance (unweighted means)

Source	df	M.S.	error df	F	P
Main Effect					
year	1	8.2160	50	0.87	0.354
group	1	100.1223	50	10.65	0.002
Interaction	1	3.6960	50	0.39	0.534
Within Cells	50	9.4053			

Group affect accounts for ∿ 17% of sample variance.

There is a significant difference between the number of scheduled PLATO sessions for 101-102 classes and for 111-112 classes over two semesters.

Number of scheduled sessions -- Spring 1976

101-102 $N_I = 8$ 111-112 $N_{II} = 20$

$t(26) = -2.367$

t this large or larger could occur by chance with p = 0.0257.

Confidence intervals for difference in population means:

.90C -5.893 to -0.957
.95C -6.399 to -0.451 $Mean_{dif} = -3.425$
.99C -7.446 to 0.596

rpb = -0.4211

17.7% of sample variance is accounted for by this effect.

14.1% of population variance is estimated to be accounted for by this effect.

	mean	s.d.	n	Σx	Σx^2
Group I	6.375	3.583	8	51.000	415.000
Group II	9.800	3.412	20	196.000	2142.000

Statistical Test on Course Usage Data

(continued)

Number of scheduled sessions -- Fall 1975

101-102 $N_I = 12$ 111-112 $N_{II} = 14$

$t(24) = -2.291$

t this large or larger could occur by chance with p = .0310.

Confidence intervals for difference in population means:

.90C	-4.055 to -0.588	
.95C	-4.412 to -0.230	$Mean_{dif} = -2.321$
.99C	-5.155 to 0.512	

rpb = -0.4237

17.9% of sample variance is accounted for by this effect.

14.1% of population variance is estimated to be accounted for by this effect.

	mean	s.d.	n	Σx	Σx^2
Group I	7.750	3.049	12	93.000	823.000
Group II	10.071	2.093	14	141.000	1477.000

APPENDIX 6.3.6

LESSON USAGE BIOLOGY

KEY TO BIOLOGY APPENDIX 6.3.6

Lesson: The descriptive title of the lesson; numbers refer to position in the biology catalog index.

Students: This number is derived from course usage statistics and includes those students who used PLATO for greater than ten minutes.

Minutes: The number of minutes that these students studied this lesson.

Average Total Time:

$$\frac{\text{\# Minutes}}{\text{\# Students}}$$ where greater than ten students used the lesson.

Grand Total Time: Total time spent in actual instruction by all students. Normally this value is 75-80% of course usage values because time involved in routing to the lesson and routing within the lesson (e.g., indices) is not included as lesson usage. In cases where this value is less than 75%, data was lost (e.g., no datafiles were attached to courses, data collection options were set to "off" within courses, or data commands were faulty within lessons). Five of the biology courses and five of the biology lessons were affected by such losses.

(continued)

LESSON USAGE -- BIOLOGY 101 AND 111, SPRING 1976

	Lesson	# Students	# Minutes	Average Total Time
1.	Tools Used in Biology	59	2,198	37
	Experimental Technique	11	340	31
	Life in a Microcosm	18	228	13
2.	Simple Chemistry I	214	17,306	81
	Simple Chemistry II*	---	------	---
3.	The Ultrastructural Concept	49	6,684	136
	Cells -- Structure and Function	260	13,793	53
	Diffusion and Osmosis	230	9,445	41
	Introduction to Water Relations	6	76	---
	Water Relations Laboratory*	---	------	---
	Surface Area/Volume in Living Systems	58	791	14
	Cell Growth	15	861	57
4.	Mitotic Cell Division†	76	3,319	44
	Mitosis†	40	1,651	41
	Meiosis (Arsenty)†	1	32	---
	Meiosis (Porch)†	1	36	---
	Embryology*†	---	------	---
	Plant Life Cycles†	11	210	19
	Hormonal Control of the Menstrual Cycle†	27	2,892	107
5.	DNA and Protein Synthesis	49	2,085	43
	DNA, RNA, and Protein Synthesis	32	929	32
6.	Enzyme Experiments	7	267	---
	Photosynthesis*	---	------	---
	Experiments in Photosynthesis*	---	------	---
	Essentials of Photosynthesis	150	2,318	15
	ATP, Anaerobic, and Aerobic Respiration	187	5,041	27
	Electron Transport Chain	122	2,885	24
	Measuring the Level of Life	57	1,236	22
	Respiration and Enzymes	62	2,858	46
	Experiments in Respiration	6	66	---
7.	Blood Typing†	2	19	---
	Drosophila Genetics†	5	39	---

*quantitative data not available
†topics not usually treated in this curriculum

(continued)

Lesson Usage -- Biology 101 and 111, Spring 1976

	Lesson	# Students	# Minutes	Average Total Time
10.	Plant Growth	29	336	12
	Plant Responses and Apical Dominance*	---	------	---
	Flowering and Photoperiod*	---	------	---
	Fruiting and Leaf Senescence*	---	------	---
	Enzyme-Hormone Interactions*	---	------	---
	Organization of the Higher Plant	24	423	18
13.	ADH and Water Balance in Humans	13	259	20
	Neuron Structure and Function	20	618	31
	Human Digestive System	130	8,102	62
	The Heart*	---	------	---
	Cardiac Cycle	79	3,367	43
	Heart Rate Regulatory Mechanisms	35	1,695	48
	Mechanics of Breathing*	---	------	---
	Elementary Psycho-physiology of Audition	13	1,395	107
14.	Physiological Basis of Learning	18	550	30

GRAND TOTAL TIME: 94,350 minutes or 1,572 hours

TOTAL # STUDENTS: 566 students, 466 of which had datafiles attached to course

*quantitative data not available

(continued)

LESSON USAGE -- BIOLOGY 102 AND 112, SPRING 1976

	Lesson	# Students	# Minutes	Average Total Time
1.	Tools Used in Biology†	7	57	---
	Life in a Microcosm†	7	58	---
3.	Cells -- Structure and Function†	51	1,903	37
	Diffusion and Osmosis†	13	349	27
	Cell Growth†	8	452	---
4.	Mitotic Cell Division	130	6,394	49
	Mitosis	210	7,868	37
	Meiosis (Arsenty)	171	6,279	37
	Meiosis (Porch)	27	2,311	86
	Embryology	171	7,035	41
	Plant Life Cycles	88	4,766	54
	Hormonal Control of the Menstrual Cycle	199	14,110	71
5.	DNA and Protein Synthesis†	159	9,079	57
	DNA, RNA, and Protein Synthesis†	61	1,319	22
6.	Essentials of Photosynthesis*†	---	------	---
7.	Vocabulary Drills for Genetics -- Part I	144	4,097	28
	Vocabulary Drills for Genetics -- Part II	38	843	22
	Elementary Probability and Mendel's Laws	70	2,860	41
	Blood Typing	32	643	20
	Genetics and Heredity	189	5,888	31
	Drosophila Genetics	115	5,472	48
	Gene Mapping in Diploid Organisms	29	1,820	63
	Plant Genetics Problems	36	1,442	40
8.	Natural Selection	35	1,547	44
	Natural Selection Experiment	27	709	26
	Comparative Serology	10	243	---
	Induced Mutations Experiment	10	118	---

*quantitative data not available
†topics not usually treated in this curriculum

(continued)

Lesson Usage -- Biology 102 and 112, Spring 1976

	Lesson	# Students	# Minutes	Average Total Time
9.	Biogeochemical Cycles	50	1,110	22
	Energy Relationships in Biological Systems	35	985	28
	Predator-Prey Relationships	16	241	15
	Buffalo -- Animal Population Experiment	7	49	---
	Population Dynamics	7	23	---
	Death Phase of Cell Growth	4	47	---
10.	Seed Germination†	1	16	---
	Plant Growth†	1	4	---
	Plant Responses and Apical Dominance†	1	28	---
	Flowering and Photoperiod†	2	60	---
13.	Human Digestive System†	1	12	---

GRAND TOTAL TIME: 90,237 minutes or 1,504 hours

TOTAL # STUDENTS: 365 students, 301 of which had datafiles attached to course

†topics not usually treated in this curriculum

(continued)

LESSON USAGE -- MISCELLANEOUS BIOLOGY COURSES, SPRING 1976

Lesson	# Students	# Minutes	Average Total Time
Simple Chemistry I	33	516	16
The Ultrastructural Concept	2	68	---
Cells -- Structure and Function	113	3,728	33
Diffusion and Osmosis	61	1,391	23
Surface area/Volume in Living Systems	23	842	37
Cell Growth	20	625	31
Mitotic Cell Division	21	482	23
Mitosis	14	215	15
Meiosis (Arsenty)	11	161	15
Embryology	11	190	17
Plant Life Cycles	18	1,566	87
DNA and Protein Synthesis	19	776	41
DNA, RNA, and Protein Synthesis	14	624	44
Essentials of Photosynthesis	1	2	---
ATP, Anaerobic and Aerobic Respiration	11	161	15
Electron Transport Chain	4	71	---
Measuring the Level of Life	1	45	---
Respiration and Enzymes	2	30	---
Vocabulary Drills for Genetics -- Part I*	---	------	---
Vocabulary Drills for Genetics -- Part II*	---	------	---
Elementary Probability and Mendel's Laws*	---	------	---
Blood Typing	23	458	20
Genetics and Heredity*	---	------	---
Drosophila Genetics*	---	------	---
Gene Mapping in Diploid Organisms*	---	------	---
Plant Genetics Problems*	---	------	---
Natural Selection Experiment	4	61	---
Induced Mutations Experiment	2	12	---
Seed Germination	1	34	---
Enzyme-Hormone Interactions	3	31	---
ADH and Water Balance in Humans	11	325	30
Neuron Structure and Function	53	2,455	46
Hormonal Control of the Menstrual Cycle	41	4,178	102
Human Digestive System	43	3,877	90
The Heart*	---	------	---
Cardiac Cycle	21	632	30
Heart Rate Regulatory Mechanisms	12	514	43
Mechanics of Breathing*	---	------	---
Elementary Psycho-physiology of Audition	2	259	---
Physiological Basis of Learning	5	30	---

*quantitative data not available

(continued)

Lesson Usage -- Miscellaneous Biology Courses, Spring 1976

GRAND TOTAL TIME: 24,503 minutes or 408 hours

TOTAL # STUDENTS: 243 students

APPENDIX 6.3.7

ON-LINE QUESTIONNAIRE

good afternoon, herrick!

Please answer the following 5 questions about the lesson you just completed. Your responses will be a great help in improving the quality of PLATO lessons...... It should only take you 2 minutes!

How would you rate the DIFFICULTY of this lesson?

1 - very difficult

2 - difficult

3 - just right

4 - easy

5 - very easy

Press the NUMBER corresponding to your choice.

Did you require ASSISTANCE during this plato session?

1 - Yes, I had problems with the TERMINAL (keyboard, excessive red lights, etc.)

2 - Yes, I needed help answering questions or understanding PLATO's instructions.

3 - Yes, BOTH 1 and 2 above.

4 - Yes, but NO ONE was available to help me.

5 - No.

Press the NUMBER corresponding to your choice.

How were you PREPARED for this plato session?

1 - My teacher gave a lecture on this topic.

2 - I did assigned reading about this topic.

3 - BOTH 1 and 2 above.

4 - None of the above, BUT I was already familiar with this topic on my own.

5 - I was not familiar with this topic before this plato session.

Press the NUMBER corresponding to your choice.

How would you rate PLATO's presentation of THIS MATERIAL relative to other learning or teaching aids such as books, slides, films, tv or tapes?

1 - excellent, the best

2 - better than some other aids

3 - no better or worse than other aids

4 - worse than some other aids

5 - very poor, the worst

Press the NUMBER corresponding to your choice.

WHY are you here now?

1 - I am IN CLASS doing a required assignment.

2 - I am IN CLASS, but this session is optional.

3 - I am NOT in class now, but this is a REQUIRED ASSIGNMENT.

4 - I am NOT in class now, and this is an OPTIONAL ASSIGNMENT.

5 - I am here entirely on my own.

Press the NUMBER corresponding to your choice.

thanks, herrick!

If you have any COMMENTS to make about this lesson or PLATO in general, press NEXT now to write them. Otherwise, you can press DATA to leave...........

APPENDIX 6.4.1

INDEX OF LESSONS

General Chemistry Index

Index of Lessons

(continued)

Index of Lessons

(continued)

Organic Chemistry Index

APPENDIX 6.4.2

GENERAL CHEMISTRY USAGE BY CLASS AND COLLEGE FOR SPRING 1976

College	Class	Students	Total Hours	Hrs/Stud
School #1	1	33	316.8	9.6
	2	26	353.6	13.6
	3	15	70.5	4.7
	4	18	205.2	11.4
	5	44	110.0	2.5
	6	25	42.5	1.7
Total		161	1,098.6	5.9
School #3	1	22	125.4	5.7
	2	34	336.6	9.9
	3	25	162.5	6.5
	4	27	70.2	2.6
	5	27	151.2	5.6
	6	20	102.0	5.1
	7	16	46.4	2.9
Total		171	994.3	5.8
School #4	1	10	61.0	6.1
	2	18	64.8	3.6
	3	28	252.0	9.0
	4	28	394.8	14.1
	5	38	163.4	4.3
	6	34	397.8	11.7
	7	20	160.0	8.0
	8	33	290.4	8.8
	9	24	158.4	6.6
	10	37	347.8	9.4
	11	23	50.6	2.2
	12	24	36.0	1.5
	13	29	40.6	1.4
	14	22	143.0	6.5
	15	29	55.1	1.9
	16	37	262.7	7.1
	17	26	111.8	4.3
Total		460	2,990.2	6.5

General Chemistry Usage by Class and College for Spring 1976

(continued)

College	Class	Students	Total Hours	Hrs/Stud
School #5	1	34	319.6	9.4
	2	40	308.0	7.7
	3	37	284.9	7.7
	4	26	150.8	5.8
	5	21	46.2	2.2
	6	7	15.4	2.2
	7	19	182.4	9.6
Total		184	1,307.3	6.4
GRAND TOTAL	37	976	6,390.4	6.5

Notes:

The negligible differences (less than 1/4%) between the usage reported in this table and the usage reported in the subject usage table can be totally attributed to the accumulation of a round-off error in the tenths of an hour decimal place.

Recall that the manner in which PLATO was used in each class was left exclusively to the discretion of the instructor and his/her department. As a result, one would expect considerable differences in the amount of use per course. Consequently, it would be erroneous to consider only usage figures in comparing effectiveness among classes or schools.

APPENDIX 6.5.1

LARS CURRICULUM BY TOPIC

Grammar

- Sentence Fragments
- Run-on Sentences
- Sentence -- Capital and Period
- Semicolons and Sentences
- Subject and Verb Agreement, Basic
- Subject and Verb Agreement, Intermediate
- Subject and Verb Agreement, Advanced
- Pronoun Case
- Pronoun Number
- Relative Pronouns
- Present Tense
- Past Tense
- Future Tense
- Present Perfect Tense
- Confusing Verbs "Lie/Lay"
- Confusing Verbs "Raise/Rise"
- Confusing Verbs "Sit/Set"
- Irregular Verbs
- Dangling Participles
- Infinitives
- Gerunds and Gerund Phrases
- Double Negatives

Punctuation

- Singular Possessives
- Plural Possessives
- Comma and Introductory Phrases
- Comma and Introductory Clauses
- Comma and Conjunctions
- Restrictive/Nonrestrictive Clauses
- Commas and Appositives
- Comma and Direct Address
- Commas with Parenthetical Expressions
- Comma with Too
- Comma with Tag Question
- Commas Used in Series
- Indirect Quotations
- Direct Quotations
- Split Quotations
- Semicolons in a Series
- Capitalizing "I," Names and Titles
- Contractions

LARS Curriculum by Topic

(continued)

Usage

Using "it's" and "its"
Using "whose" and "who's"
Using "their," "there" and "they're"
Using "your" and "you're"
Using "to," "two" and "too"
Confusing Word Pairs
All right/All ready/All together

Spelling

"S" Plurals
"ES" Plurals
"Y" Plurals
"O" Plurals
"F" Plurals
Irregular Plurals
Vowel Changing Plurals

APPENDIX 6.5.2

INDEX OF NON-LARS LESSONS

Capitalization

- Common and Proper Nouns
- Capitalization Diagnostic Test
- Capitalization of Names and Titles
- Capitalization II
- Capitalization III

Composition

- Assembling Sentences and Paragraphs
- Verb Quiz and Theme Revision Symbols
- Topic Sentences
- Irrelevant Details in Paragraphs

Editing

- Editing a Paragraph I
- Editing a Paragraph II
- Editing a Paragraph III
- Editing a Paragraph IV
- Editing a Paragraph V
- Editing a Paragraph VI
- Editing a Paragraph VII
- Proofreading

Grammar

- Grammar Index
- Parts of Speech
- Test on Grammar and Usage
- Complete Sentence
- Recognizing Sentences
- Subjects and Predicates
- Subject, Verb, Complement
- Subject-Verb Agreement I
- Subject-Verb Agreement II
- Pronoun-Verb Agreement
- Pronoun Agreement
- Pronouns
- Possessive and Subjective Pronouns
- Verbs, Basic
- Verb Tense I
- Verb Tense II

Index of Non-LARS Lessons

(continued)

Grammar (continued)

Poetry

Punctuation

Index of Non-LARS Lessons

(continued)

APPENDIX 6.5.3

SAMPLE STUDENT NOTES

Excerpts from a note collecting program which allows both student and instructor to report errors and comment on the various lessons which are part of the Language Arts Routing System.

Student -- I liked it a lot, it was helpful.

Student -- Wonderful

Student -- PLATO is a wonderful thing to have.

Student -- I think that PLATO is good and that every home should have one.
Student (Response) -- At no cost.

Student -- I think PLATO is very educating, and also a lot of fun. I am taking Accounting and English and I have learned a great deal of both. If anyone is reading my letter Hi and have a nice day.
Staff (Response) -- Hello, ------. People do indeed read student notes. I hope you are enjoying PLATO. If you have any problems or questions, ask them here and we'll see what can be done.

Student -- Hi everyone, how's life. I just finished a lesson on punctuation and I did good at least thats what PLATO said. Thanks for your response. I am learning a lot of things I couldn't understand before. Well I talk too much so bye for now and I hope you and everybody else better in their work.
Staff (Response) -- Thank you ------.

Student -- Some of this jive is a lot of smack. It's to repatious.

Student -- I like the way PLATO drills you on the pronouns and etc. Also I like the way he adds his little touch of humor.

Instructor -- Two of sent frag diag questions call for distinguishing between restrictive and nonrestrictive phrases. This has nothing to do with recognition of frags and should perhaps be omitted. Take out the sentence with wrong internal punct. Frags after semicolons also confuse the issue, I think. I know correcting this would be drastic.

Staff (Response) -- Thanks for the positive criticism. Will correct the errors. This exactly the type of comment/observation that is looked for and appreciated.

Student -- I think this is a wonderful machine. As you can see that I enjoy it very much. I hope who ever invented this machine that they will keep up the good work.
Student #1 (Response) -- Dear PLATO, I think your way of teaching is really fantastic. I am sure I will learn a great deal from you. I sure hope I can use you in some of my future classes.

Instructor -- This program read LARSDEMO Word Group; it was very confusing.
Staff (Response) -- I believe I've fixed this bug. Please report it again if you encounter it. Add as much detail about how you reached the error as possible.

Student -- This was a good lesson.
Student #1 (Response) -- This isn't very helpful.
Student #2 (Response) -- It is so very helpful.
Student #3 (Response) -- I think that PLATO can help alot of people because its fun.
Student #4 (Response) -- This way of teaching is out of sight.
Staff (Response) -- We're glad you enjoy it.

Student -- The lessons are so well presented, you just can't miss.
Student #1 (Response) -- All the responses were premature.

Student -- Lesson number ---. The one on possevies is way to long. It should be shortened down to about 20 or 30. Plus it doesn't take into account human errors, i.e., pushing the wrong button, the ability to go back when you see an error that you have made. It should also make spelling a lesser evil than misplacement of the ----. I HOPE YA'LL WILL SEE ABOUT CORRECTING THAT.
Staff (Response) -- Thanks, -----. We are already preparing a version of ---------- that will cut the number of problems down to -----. It is ungodly long, I'll admit!

Student -- The test on singular and plural possessives, is the hardest test I have taken on PLATO. It sure helps a lot.

Student -- Dear PLATO, I think this is a marvelous idea about me working on a computer it is a very big help to me and I wish I had one of my very own. This wonderful machine also helps me to do my lesson. I think every student wouldn't mine haven't one. Thank you very much.
Student #1 (Response) -- I'm with you.
Student #2 (Response) -- Fantastic

Student -- This lesson has really helped to increase my writing skills. Thank you. You're getting me to believe in you.

Student -- I really enjoy working and learning the PLATO way. This is not only fun, it is very helpful.
I LOVE YOU, PLATO.
I LOVE YOU, PLATO.
Gratefully yours,

Staff -- To those students in course -------, who got messed up today; sorry people, a programming error sent you to the wrong place, thus making it impossible for you to continue. The error is now fixed; sorry for the inconvenience.

Student --This lesson is really worth learning. I wish I had learned this in high school.
Student #1 (Response) -- Me too.
Student #2 (Response) -- This dumb machine is alright. I don't think I could have found a better tutor.
Student #3 (Response) -- Me either.

Student -- Who or whom are you?
Staff (Response) -- Who is whom? The machine isn't a person; it just presents individualized lessons written by various people. There are some people (like me) who have the responsibility of reading student comments and seeing that the programs continue to work correctly. When an error is discovered, we try to fix it. We hope you continue to enjoy PLATO.

APPENDIX 6.6.1

COMMUNITY COLLEGE MATHEMATICS LESSONS SUMMARIZED BY TOPIC AREA

	# lessons	# hours	# of lessons which have these structural features							
			td+b	q	uam	tut	game	calc	sim.	dr.
I. Whole Numbers, Divisibility and Fractions	15 2	9.3 open-ended	14	7	4	9	3	7	1	
II. Decimals and Percent	17	11.4	17	15		16		4	1	1
III. Signed Numbers	14	5.8	13	5	12	9	2	1	4	1
IV. Set Theory, Algebraic Expressions, and Linear Equations	26	17.8	25	2	2	13	1		1	11
V. Algebraic Fractions and Quadratic Equations	8	4.9	8							7
VI. Plotting Points and Graphing Straight Lines and Simultaneous Equations	21	10.6	17	2	19	16	2	4		
VII. Trigonometry and Logs	10	4.8	10		9	9		5		
VIII. Miscellaneous	9	6.9	8	2	2	8		1	4	
IX. Functional Plotters	2	open-ended							2	
TOTALS	124	71.5 (+4 open-ended)	112	33	48	80	8	22	13	20
Lessons produced at CMG	59	32.7 (+2 open-ended)	57	9	40	48	0	11	6	0
Lessons produced at CCC	52	34.1	50	22	3	29	2	7	3	20
Lessons produced elsewhere	13	4.8 (+2 open-ended)	5	2	5	3	6	4	4	0

APPENDIX 6.6.2

NUMBERS OF STUDENTS AND HOURS OF USAGE
COMMUNITY COLLEGE MATHEMATICS LESSONS--FALL 1974 THROUGH SPRING 1976

	School #1		School #2		School #3		School #4		School #5		TOTALS	
	# sts.	# hrs.	# sts.	# hrs.	# sts.	# hrs.	# sts.	# hrs.	# sts.	# hrs.	# sts.	# hrs.
Fall 1974 (sem/qrtr)	142	422	113	259	319	839	0	0	0	0	574	1520
Winter 1975† (sem/qrtr)	210	853	--	--	--	--	--	--	--	--	210	853
Spring 1975 (sem/qrtr)	179	1111	194	1279	304	927	0††	0††	81*	163*	758	3480
Summer 1975	59	399	203	1546	114	244	55**	121**	58	101	489	2411
Fall 1975	148	366	66	254	360	1420	107	364	71	246	752	2650
Spring 1976	180	868	225	1472	257	1635	217	509	161	675	1040	5159
TOTALS	918	4019	801	4810	1354	5065	379	994	371	1185	3823	16,073

† School #1 was on the quarter system during the 1974/75 school year. Consequently, it is the only school with a 1975 winter quarter. All schools were on the semester system during 1975/76.

†† There were 866 hours of math usage under a multiple record.

* There were 77 hours of additional math usage under a multiple record.

** There were 67 hours of additional math usage under a multiple record.

APPENDIX 6.6.3

SUMMARY OF PLATO USAGE ACCORDING TO TYPE OF MATHEMATICS COURSE

	# courses	# instructors	# sts.	# hrs.	# hrs/st.
I. Related Math for Vocational Students	32	8	692 (18.1%)	4337 (27.0%)	6.3
II. Algebra	37	15	901 (23.6%)	3646 (22.7%)	4.0
III. Intermediate Algebra	28	12	602 (15.7%)	3144 (19.6%)	5.2
IV. GED Math	22	8	732 (19.1%)	2204 (13.7%)	3.0
V. Preparatory Math	9	6	140 (3.7%)	362 (2.2%)	2.6
VI. Technical Math	6	5	122 (3.2%)	543 (3.4%)	4.5
VII. Learning Center	10	3	174 (4.6%)	497 (3.1%)	2.9
VIII. Miscellaneous Courses	22	13	460 (12.0%)	1340 (8.3%)	2.9
TOTAL	166	51	3823	16,073	4.2

APPENDIX 6.6.4

DISTRIBUTION OF TIME IN TOPICS AND LESSONS FOR FIVE GROUPS OF SELECTED COURSES

Miscellaneous Information about the Course Groups Contained in This Table

	School	# Inst	# Stu	# Hrs	Ave Hrs per Stu	Scheduling Pattern
I. Ten Vocational Courses -- Spring 1976	2	5	216	1,455	6.7	"1/wk" and "h-out"
II. Four Algebra Courses -- Fall 1975	3	3	109	491	4.5	1 course "opt" 3 courses "1/wk" 3 courses "h-out"
III. Three Algebra Courses -- Spring 1976	3	3	92	683	7.4	1 course "1/wk" 2 courses "clump"
IV. Four Intermediate Algebra Courses -- Fall 1975	1	2	107	319	3.0	"opt"
V. Three Intermediate Algebra Courses -- Spring 1976	1	2	77	548	7.1	"clump"

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

I. Ten Vocational Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
A. DIVISIBILITY AND FRACTIONS					348 hours	44.9%
Exercises--Equal Fractions, Mixed #s	15	79	3,756	48		
Divisibility Rules/Reducing Fractions	60	76	4,705	62		
Exercises--Arithmetic Operations on Fractions	60	68	3,015	44		
Adding and Subtracting Fractions with Unlike Denominators	40	53	3,497	66		
Fractions on the Number Line	40	42	3,187	76		
Finding the Greatest Common Denominator	60	40	1,651	41		
Introduction to Fractions	60	17	431	25		
Claim Game	15	15	442	29		
Prime Factorization of Whole Numbers	35	12	205	17		

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

I. Ten Vocational Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
B. DECIMALS AND PERCENT					280 hours	36.1%
Reading and Writing Decimals	60	72	4,099	57		
Percent-Decimal-Fraction Conversions	60	54	4,502	83		
Rounding Decimals	30	54	2,545	47		
Adding and Subtracting Decimals	60	42	2,075	49		
Multiplying and Dividing Decimals	60	40	2,381	60		
Keeping a Balanced Checkbook	60	17	432	25		
Subtracting Decimals	30	6	316	53		
Math Review Drills I	35	6	209	35		
Dividing Decimals	60	6	86	14		
Multiplying Decimals	30	5	86	17		
Adding Decimals	30	5	76	15		
Word Problems with Percent--Introduction	30	1	10	10		
C. SIGNED NUMBERS					102 hours	13.2%
Introduction--Thermometer and Sea Level	10	54	577	11		
Adding and Subtracting on the Number Line	45	43	2,130	50		
Eggdropper	10	16	653	41		
Signed Number Word Problems on Temperature and Sea Level	15	15	415	28		

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

I. Ten Vocational Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
C. SIGNED NUMBERS (continued)						
Addition and Subtraction of Signed Numbers--Bank Stories	30	13	445	34		
Multiplication of Signed Numbers--Bank Stories	30	12	250	21		
Signed Numbers Game--West	15	11	708	64		
Double Signs (Flipping) and Multiplication (Patterns)	15	11	179	16		
Addition of Signed Numbers	35	11	179	16		
Multiplication (using the running man)	45	11	167	15		
Exercises--Adding and Subtracting	30	11	136	12		
Subtraction of Signed Numbers	25	10	212	21		
Math Review Drills II	35	2	47	23		
D. SET THEORY, ALGEBRAIC EXPRESSIONS AND SOLVING LINEAR EQUATIONS					9 hours	1.2%
Introduction to Sets	20	6	140	23		
Symbols of Grouping	30	5	104	21		
Word Problem Drills I	15	5	86	17		
Solving Linear Equations	180	4	134	33		

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(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

I. Ten Vocational Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
D. SET THEORY, ALGEBRAIC EXPRESSIONS AND SOLVING LINEAR EQUATIONS (continued)						
Laws of Exponents	40	3	53	18		
Binomial Products: (x+2)(x-3) etc.	45	2	16	8		
Solving Quadratic Equations by Factoring	60	1	11	11		
Factoring Polynomials	40	1	1	1		
E. PLOTTING POINTS, GRAPHING STRAIGHT LINES AND SIMULTANEOUS EQUATIONS					8 hours	1.0%
Tic-Tac-Toe.	30	8	95	12		
Slope of a Line	30	3	64	21		
Intercept of Straight Lines	15	3	28	9		
Introduction to Systems of Equations	15	2	72	36		
Exercises on Solving 2x2 Systems of Equations	15	2	54	27		
How to Write Solutions of Systems of Equations	15	2	47	24		
Graphing Straight Lines--Table of Values	30	2	13	7		
Solving 2x2 Systems by Substitution	45	1	57	57		
Independent Systems of Equations and Numbers of Solutions	30	1	17	17		

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

I. Ten Vocational Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
E. PLOTTING POINTS, GRAPHING STRAIGHT LINES AND SIMULTANEOUS EQUATIONS (continued)						
Solving 2x2 Systems by the Addition-Subtraction Method	45	1	16	16		
Graphing Any Line in the Form ax+by+c=0	30	1	5	5		
F. SLIDE RULE AND SQUARE ROOT					28 hours	3.6%
Finding the Square Root	30	29	1,364	47		
Slide Rule	120	8	335	42		

TOTAL TIME ALL TOPICS: 775 hours

% of on-line time not accounted for by these lessons = 47%

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

II. Four Algebra Courses -- Fall 1975

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
A. MULTIPLES OF WHOLE NUMBERS, DIVISIBILITY, AND FRACTIONS					59 hours	17.8%
Equal Fractions	60	45	1,375	31		
Fractions on the Number Line	40	31	955	31		
Exercises--Arithmetic Operations on Fractions	60	18	476	27		
Introduction to Fractions	60	12	212	18		
Finding the Greatest Common Divisor	60	11	332	30		
Claim Game	15	10	189	19		
Divisibility Rules/Reducing Fractions	60	1	17	17		
B. DECIMALS AND PERCENT					6 hours	1.8%
Decimal Skills--Introduction	10	11	37	3		
Reading and Writing Decimals	60	6	251	42		
Keeping a Balanced Checkbook	60	2	39	19		
Multiplying and Dividing Decimals	60	2	16	8		
Adding and Subtracting Decimals	60	1	10	10		
Rounding Decimals	30	1	2	2		

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

II. Four Algebra Courses -- Fall 1975

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
C. SIGNED NUMBERS					149 hours	44.9%
Adding and Subtracting on the Number Line Number Line	45	77	5,086	66		
Exercises--Adding and Subtracting	30	60	2,085	35		
Multiplication (using the running man)	45	51	900	18		
Signed Numbers Game--West	15	13	732	56		
Eggdropper	10	4	122	30		
Double Signs (Flipping) and Multiplication (Patterns)	15	3	9	3		
D. SET THEORY, ALGEBRAIC EXPRESSIONS AND SOLVING LINEAR EQUATIONS					115 hours	34.6%
Introduction to Sets	20	79	1,981	25		
Laws of Exponents	40	48	2,809	59		
Solving Linear Equations	180	27	1,039	39		
The Distributive Law	30	25	740	30		
Binomial Products: (x+2)(x-3) etc.	45	8	114	14		
Symbols of Grouping	30	5	175	35		
Powers and Roots of Natural Numbers	30	3	32	11		

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

II. Four Algebra Courses -- Fall 1975

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
E. PLOTTING POINTS AND GRAPHING STRAIGHT LINES						
Tic-Tac-Toe	30	9	127	14	3 hours	0.9%
Battleship	30	5	32	6		

TOTAL TIME ALL TOPICS: 332 hours

% of on-line time not accounted for by these lessons = 32%

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(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

III. Three Algebra Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
A. MULTIPLES OF WHOLE NUMBERS, DIVISIBILITY AND FRACTIONS					84 hours	16.7%
Fractions on the Number Line	40	47	1,974	42		
Equal Fractions	60	28	772	28		
Adding and Subtracting Fractions with Unlike Denominators	40	21	1,456	69		
Exercises--Arithmetic Operations on Fractions	60	16	295	20		
Finding the Greatest Common Divisor	60	11	458	42		
Divisibility Rules/Reducing Fractions	60	4	99	25		
B. DECIMALS AND PERCENT					6 hours	1.2%
Reading and Writing Decimals	60	4	54	14		
Adding and Subtracting Decimals	60	3	105	35		
Multiplying and Dividing Decimals	60	3	54	18		
Decimal Skills: Introduction	10	3	8	3		
Keeping a Balanced Checkbook	60	2	98	49		
Rounding Decimals	30	1	19	19		
Comparing Decimals	60	1	13	13		

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

III. Three Algebra Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
C. SIGNED NUMBERS					110 hours	21.9%
Adding and Subtracting on the Number Line	45	69	3,658	53		
Exercises--Adding and Subtracting	30	48	1,763	37		
Multiplication (using the running man)	45	41	882	22		
Signed Numbers Game--West	15	10	121	12		
Eggdropper	10	4	92	23		
Double Signs (Flipping) and Multiplication (Patterns)	15	4	53	13		
Introduction--Thermometer and Sea Level	10	4	14	4		
D. SET THEORY, ALGEBRAIC EXPRESSIONS, AND SOLVING LINEAR EQUATIONS					136 hours	27.0%
Introduction to Sets	20	72	1,921	27		
Laws of Exponents	40	33	2,240	68		
Solving Linear Equations	180	21	2,862	136		
Evaluating Algebraic Expressions	60	15	617	41		
The Distributive Law	30	7	190	27		
Binomial Products: (x+2)(x-3) etc.	45	6	133	22		
Special Products I	25	4	148	37		
Symbols of Grouping	30	1	33	33		

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

III. Three Algebra Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
E. PLOTTING POINTS AND GRAPHING STRAIGHT LINES					167 hours	33.2%
Graphing Straight Lines--Table of Values	30	41	4,626	113		
Tic-Tac-Toe	30	41	742	18		
Slope of a Line	30	33	2,475	75		
Intercept of Straight Lines	15	33	573	17		
Graphing Any Line in the Form y=mx+b	30	13	777	60		
Point-Slope Form	30	11	491	45		
Battleship	30	9	267	30		
Graphing Lines in the Form ax+by+c=0	60	2	50	25		
The Lines y=b and x=c	30	1	--	--		

TOTAL TIME ALL TOPICS: 503 hours

% of on-line time not accounted for by these lessons = 27%

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

IV. Four Intermediate Algebra Courses -- Fall 1975

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
A. SET THEORY, ALGEBRAIC EXPRESSIONS AND SOLVING LINEAR EQUATIONS					39 hours	17.5%
Laws of Exponents	40	23	427	19		
Factoring Polynomials	40	22	600	27		
Factoring Quadratic Polynomials	60	20	377	19		
Prime Factorization of Whole Numbers	35	20	300	15		
Binomial Products; (x+2)(x-3) etc.	45	18	262	15		
Special Products I	25	14	233	17		
Solving Quadratic Equations by Factoring	60	9	126	14		
B. PLOTTING POINTS					63 hours	28.3%
Battleship	30	102	2,758	27		
Tic-Tac-Toe	30	101	1,018	10		
C. GRAPHING STRAIGHT LINES					108 hours	48.4%
Graphing Straight Lines--Table of Values	30	68	2,543	37		
Slope of a Line	30	36	1,260	35		
Intercept of Straight Lines	15	34	259	8		
More Exercises on Linear Equations and Straight Lines	60	25	586	23		

37.1

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

IV. Four Intermediate Algebra Courses -- Fall 1975

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
C. GRAPHING STRAIGHT LINES (continued)						
Graphing Lines in the Form ax+by+c=0	60	21	952	45		
Graphing Any Line in the Form y=mx+b	30	20	664	33		
The Lines y=b and x=c	30	20	222	11		
D. SIMULTANEOUS EQUATIONS					13 hours	5.8%
Introduction to Systems of Equations	15	20	139	7		
Exercises on Solving 2x2 Systems of Equations	15	15	90	6		
Independent Systems of Equations and Numbers of Solutions	30	10	151	15		
How to Write Solutions to Systems of Equations	15	9	64	7		
Solving 2x2 Systems by Graphing	30	9	41	5		
Introduction to Algebraic Methods of Solving 2x2 Systems	30	8	48	6		
Solving 2x2 Systems by Substitution	45	7	219	31		
Solving 2x2 Systems by the Addition-Subtraction Method	45	4	23	6		

TOTAL TIME ALL TOPICS: 223 hours

% of on-line time not accounted for by these lessons = 30%

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

V. Three Intermediate Algebra Courses -- Spring 1976

	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
A. PLOTTING POINTS					13 hours	3.0%
Tic-Tac-Toe	30	73	559	8		
Battleship	30	15	247	17		
B. GRAPHING STRAIGHT LINES					243 hours	56.8%
Graphing Straight Lines--Table of Values	30	72	4,505	63		
Slope of a Line	30	66	3,310	50		
Intercept of Straight Lines	15	66	517	8		
Graphing Any Line in the Form y=mx+b	30	61	2,417	40		
The Lines y=b and x=c	30	54	812	15		
Graphing Any Line in the Form ax+by+c=0	60	53	3,028	57		
C. SIMULTANEOUS EQUATIONS					172 hours	40.2%
Independent Systems of Equations and Numbers of Solutions	30	60	1,069	18		
Introduction to Systems of Equations	15	59	564	10		
How to Write Solutions to Systems of Equations	15	58	1,381	24		
Solving 2x2 Systems by Graphing	30	54	658	12		
Introduction to Algebraic Methods of Solving 2x2 Systems	30	50	469	9		

(continued)

Distribution of Time in Topics and Lessons for Five Groups of Selected Courses

V. Three Intermediate Algebra Courses -- Spring 1976

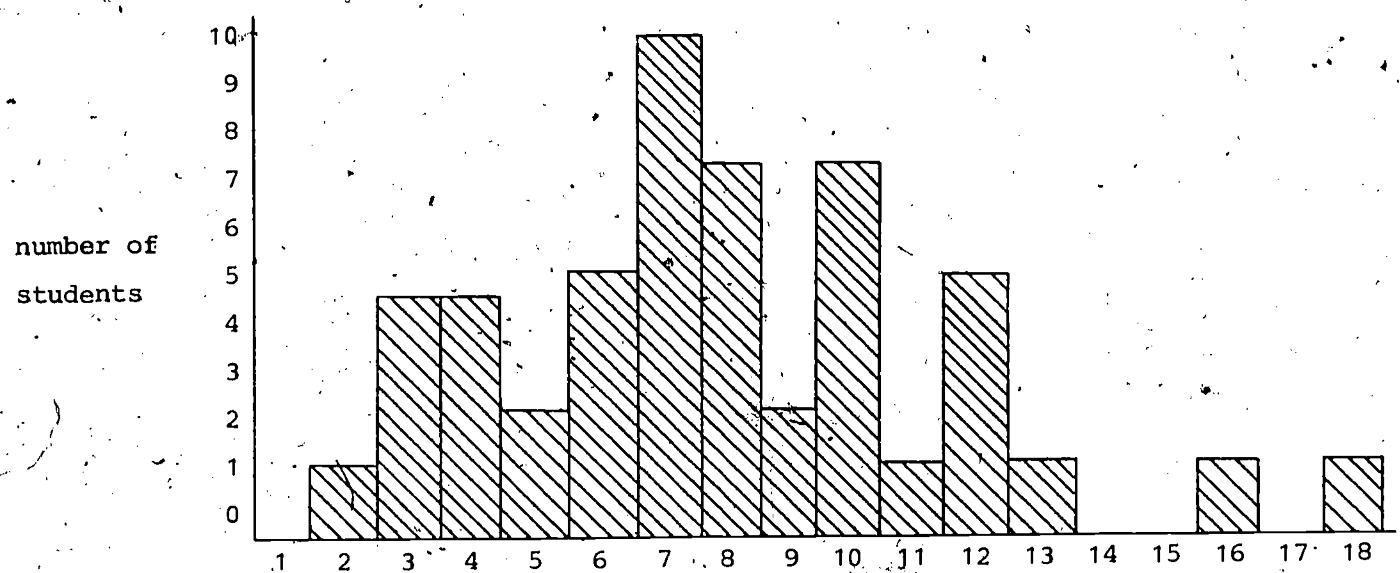
	Est. Time (min)	#Stu in Lesson	Time in Lesson (min)	Ave Time in Lesson per Stu	Total Time in Topic	% of Time in Topic
C. SIMULTANEOUS EQUATIONS (continued)						
Solving 2x2 Systems by Substitution	45	48	3,538	74		
Solving 2x2 Systems by the Addition-Subtraction Method	45	37	1,899	51		
Exercises on Solving 2x2 Systems of Equations	15	34	675	28		
Posttest for Simultaneous Equations	20	3	46	15		

TOTAL TIME ALL TOPICS: 428 hours

% of on-line time not accounted for by these lessons = 22%

APPENDIX 6.6.5

DISTRIBUTION OF TIME ON PLATO -- LINE STUDY



Mean = 7.9 hr. Max = 17.5

S.D. = 3.4 Min = 2.1

51 students total

APPENDIX 6.6.6

LESSONS COMPLETED → LINE STUDY