Project 'Clear Skies': Teaching Computer Science by Computer Based Training and Electronic Messaging in China

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This paper describes the first five months of a computer-based training project which is using Canadian technology to teach a first-year-honours course in Computer Science at East China Normal University in Shanghai.

The project has two objectives: to demonstrate that a Canadian courseware and delivery system can function in the Chinese educational and telecommunications environment; to study the feasibility of adapting the CBT system for the creation and delivery of courseware in the Chinese language.

The courseware used in the project was developed co-operatively by Softwords and North Island College, and has been demonstrated to be effective in a Canadian environment. However, North Island College has created a delivery system which is well suited to the many small communities it serves. East China Normal University, in contrast, is located in the city of Shanghai which has a population equal to a half that of all of Canada. These differences help clarify common implementation problems, and the concept of CBT implementation engineering is discussed. Ten substantive factors are identified that can affect the implementation process. Nine of these factors have been identified as relevant during Project 'Clear Skies' and dealt with successfully.

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1. INTRODUCTION

'Clear Skies' is an ambitious project to use computer-based training (CBT) and electronic communications to teach a first-year honours course to large numbers of students in China. East China Normal University began a trial in November 1985, with a view to the eventual delivery of the course to what will potentially be one of the world's largest open systems: a satellite-based delivery system with many hundreds of receiving sites spread across that vast territory.

Without CBT and electronic communications, China would need many, many thousands of instructors to deliver this kind of knowledge in the fashion desired. It simply cannot afford to wait for a generation of training. It is anticipated therefore that these pressures will help ensure the creation of a natural, open system in which learning, and CBT, will thrive.

This project represents a significant advance in a number of areas:

(1) Designing a CBT course of this magnitude demands that software engineering principles must be applied to the design and production of cost- and time-effective courseware. In addition, a new concept, CBT implementation engineering, is designed to cover the systematic process by which large-scale CBT courseware is integrated into a specific learning environment.

(2) Over the past eighteen months the courseware has been rigorously and successfully beta tested with well over a hundred college students in B.C. (Project 'Blaze'). Not only has this demonstrated that students completing the course emerge with excellent programming skills and mastery of the computer-science concepts involved, but it is possible for students to take the course on many different types of computer (VAX, PDP/11, Optimum, Tandy 1000) which show the high degree of portability which current software and courseware methodology affords.

(3) The students in China are using yet another type of computer, the CEMCORP ICON. This was the first microcomputer to be specifically designed for use within an educational environment, and uses a UNIX-like operating system (QNX) with a 2.5 Mbps Local Area Network (LAN). The Chinese students are using courseware implemented in NATAL (the Canadian *NAT*ional *A*uthorising *L*anguage) and are using WATCOM Pascal as the algorithmic language in this course.

2. COURSE DESIGN

The design of the courseware began with a close examination of the needs of the learners and the learning environment in which the CBT course would exist. In order to match existing courses offered at universities in Canada and the U.S., the content focused on the teaching of first-year computer science in terms of the following learner objectives: writing Pascal code without syntax errors, following through the steps of good problem-solving techniques, and mastering the selection of appropriate algorithms and data structures to solve a specific problem. The environment demanded that the learners be able to work through the material with a minimum of tutor support, to work with hardware and software that was initially unfamiliar, and to be able to work in isolation. Finally, the content was presented on a monochrome text screen, with a printer as the only other peripheral device.

Because it was to be a very large, text-based course, it was important that the course content could be easily edited, not only during course development, but also during the first year of delivery. NATAL encourages the separation of data (the course content) from code (the NATAL software which presents the course content to the learner). It was a natural decision therefore to create

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a system that includes a Driver, a Dataloader and data files. The Driver presents the course content to the learner according to structures that are partially pre-determined, partially determined by flags in the data, and partially determined by the learner's response. The content is first written in editable data files, and then loaded into NATAL data files with the Dataloader. NATAL data files are accessed by the Driver as required during runtime. This separation of structure and content (code and data) also allows parallel development of both, and speeds up the development process.

The course, which is the equivalent of a full-year's course, is divided into 30 Units, where each Unit represents approximately one week's work. To complete a Unit, the learner must do a Unit from the CBT course, some readings from a textbook, and an assignment that is marked by the course tutor.

The Driver design uses tracking records to ensure a programmed learning approach. Each Unit contains two to seven Lessons. Each Lesson consists of Instruction, Practice and Test. Access of Instruction and Practice are optional. But a Lesson is only considered to have been completed when the Test has been passed. Any completed Units or Lessons can be specifically accessed, but it is not possible to access a Unit or Lesson if the prerequisite has not been completed. The learner is about to Quit (i.e. temporarily stop working through the CBT material) at any point in the course.

This approach compensates for limited access to the course tutor. The learner first masters an understanding of the concepts, then goes through a simulated application of the concepts to a specific problem before actually practising the skills in an operating system.

3. TESTING THE SYSTEM IN B.C.

Beginning in September 1984, the course was beta-tested in North Island College. North Island College serves a region of over 80,000 square kilometres, which covers most of Vancouver Island and parts of the central B.C. coast. Within this vast region the college does not have a natural geographic centre, nor does it have a single large community. Courtenay, with a population of only 8992, is typical of the *larger* communities in the region, and North Island College currently operates eighteen learning centres in communities as diverse as Port Alberni and Waglisla.

CBT offered North Island College the opportunity to deliver courses in high-technology which would be difficult using other delivery methods. Conversely, North Island College provided a very real testing ground for demonstrating that the course would work with real students. Initially, North Island College began offering the course using a VAX 11/750, with leased lines to Campbell River, Courtenay and Port Alberni. This worked extremely well, but as the numbers of students increased to over one hundred, response time decreased, and it became impractical to also use the VAX for development work. The CBT course was therefore transferred on to three super-microcomputers (ISI Optimum V Systems) which were located in the three communities, but still networked together. More recently the course has been ported to Tandy 1000 microcomputers, so that it can be offered in communities which are too small to need even a super-microcomputer.

Regardless of where the learner is taking the course with North Island College, he or she is assigned a local tutor who meets with the learner at registration and explains the components of the course and how they interact. The learner is able to use the on-line resources of the computer both for the delivery of the material and for completing programming assignments. The local tutors in the learning centres are key players in the learning process. They meet with the learner on a 'needs dictated' basis to discuss problems and answer questions. In the larger communities, these tutors will have sufficient expertise to mark the assignments that accompany each Unit of on-line instruction and thus provide guidance to the learner on problem development and programming style. In the smaller communities, the role of the local tutor is to provide the support and motivation which is so crucial for the isolated learner. In this case, the assignments are marked by a course tutor, who will also be the local tutor in a larger community. However, in both cases the bulk of the tutor/learner interaction is done electronically, so that students throughout the system can be assured of having an electronic tutor 'on duty' at virtually any time of the day or night that the college is open.

A day in the life of these learners does not begin in a classroom, but in the computer learning centre. There they *login* to their individual account and work through a Unit of CBT, based on the assigned text reading outlined in their course study manual. When they have completed the on-line Unit, they use the electronic network to obtain an assignment that can be printed on the local printer in their centre. Following a period of off-line work analysing the problem and composing first a pseudocode algorithm and then the Pascal solution, they return to the material. Using a full-screen editor and Pascal compiler, they develop and document their program using the technique taught in the CBT Unit.

Once they are satisfied with their effort, they produce a 'script' that includes a 'listing' of the program and a sample execution, and send it electronically to the tutor. The tutor receives the assignment and post it for marking, at the same time promoting the learner to the next CBT Unit. For each student, an electronic 'folder' is kept holding the student assignments and the tutors comments on them. Although it is normal, in the larger centres, for a tutor to mark the assignments of his own students, a centralised posting of assignments allows several tutors to share the marking load.

If the assignment is deficient in some way, the tutor will suggest how it might be improved and return it electronically. Learners have universally co-operated in improving their assignments. Using such a 'mastery approach' it may take them a little longer to complete the course, but they emerge with excellent programming skills.

Naturally one of the first criteria for a tutor is reasonable typing skills, since he or she can expect to get quite a lot of electronic communications. However, the tutor also needs to be aware that communicating in this way requires more sensitive interpersonal skills than are needed in a classroom. The tutor is automatically notified each time a learner finishes a Unit or receives an assignment. The course tutor and the local tutor see all of the 'comments' that learners make about the CBT material. The course tutor checks these for validity, and

in an emergency can fix the offending item. Comments and valid complaints are archived and forwarded to the development team for the ongoing maintenance of the course. As a result, learners always get a quick answer to any complaint and the information is used to dynamically improve the course.

Keeping track of learners in such an open, self-paced environment is not an easy task. Fortunately, the CBT course was carefully designed to produce 'date stamped' records at the beginning and end of each Unit, and at the end of each Lesson. These were supplemented with records noting when the learner registered, if and when they went 'on hold' (students are allowed to go 'on hold)' for up to six months in a course) or bought an extension, and what his or her final examination mark was or when he or she was removed from the course.

To analyse this information a system called 'Gradebook' was constructed. It began as a Pascal assignment and was expanded to become a very useful tool. It provides the course tutor with reports such as the detailed progress of each student, a list of students who are behind the predicted achievement rates and the average times for completing each Unit.

During the beta test period over a hundred students enrolled in the course. Attrition ran at 33%, with the vast majority of these being people who never actually began the course. This figure is also low when compared to the 60% quoted by many universities and colleges for similar courses. Undoubtedly a number of factors are involved, several of which would lead one to expect the college to have a *higher* attrition rate than traditional institutions. However, the learners tend to be older than those who are traditionally thought of as first-year students, and better able to handle their time commitments. The self-paced nature of the course also allows learners to be away for several weeks for work or health-related reasons, and still able to pick up where they left off. In the traditional classroom situation it would be hard, if not impossible, to make up for lost time in such a demanding course.

4. CANADA – CHINA COLLABORATION

Project 'Clear Skies' is designed to facilitate the growth of productive linkages between Canadian and Chinese expertise in CBT. The idea of such collaboration came as a result of contacts made at ECNU by Don Stenton of the University of Victoria. Dr Stenton has used NATAL in the teaching of university level courses in physics, and has been involved in earlier joint projects between the University of Victoria and ECNU.

The project has two specific objectives:

(1) To demonstrate that a Canadian courseware creation and delivery system can function in the Chinese educational and telecommunications environment.

(2) To study the feasibility of adapting the CBT system for the creation and delivery of courseware in the Chinese language.

Since large numbers of students at ECNU can read and write English fairly well, it was decided to use a modified English version of the course to achieve the first objective. Once information about the requirements of Chinese users of the system has been obtained, the scope of the feasibility study of inputing and displaying the data using Chinese characters will be defined. This study will, as a minimum, consider interfaces with existing hardware and software for display and response handling, phonetic spelling to ideogram conversion, and special documentation needs. The Chinese already have considerable expertise in this area and will be called upon to help establish guidelines.

5. ECNU

In sharp contrast to the North Island College region Shanghai is home for approximately 12 million people. However, getting from one place to another is a serious problem the residents face each day. It takes about 30 minutes to drive by car from downtown Shanghai to the university campus. Since the average person in China does not own a car, most students must make the journey by bicycle each day through streets that are extremely crowded with pedestrians, buses, trucks and other cyclists. Cycling and walking are the most common modes of transport, since the buses are always over-full and most people seem to avoid taking them.

ECNU was established in 1951 with its major goals being to provide teacher training and to do further research in the area of educational science. To promote adult education, the university offers a variety of correspondence and evening courses, and ECNU also holds examinations for individuals who are not enrolled in university courses, but who study on their own. Because of the great importance the university attaches to the study of educational science, the Institutes of Educational Science and of Modern Educational Technology were established.

There are nearly 7000 undergraduate students at ECNU and about 5500 correspondence and evening-course students. In addition, approximately 22000 people sit for examinations at ECNU each year after completing their studies at home. However, despite this, the small proportion of the population that is highly trained remains a serious problem; a problem that was further exacerbated during the turmoil of the Cultural Revolution.

6. INSTITUTE OF MODERN EDUCATIONAL TECHNOLOGY

At ECNU, Project 'Clear Skies' is firmly established within the Institute of Modern Educational Technology. The Institute is the only faculty in China working primarily in CBT and its head, Professor Wan Jairuo, is the only full professor in educational technology in China. As such, the Institute is regarded as the leading organisation for CBT in China. Members of the Institute are very eager to develop courseware and to use it for distant delivery.

As director of the Institute, allocation of the Institute's resources are Professor Wan's responsibility. One of the authors of the present paper, Gong Shikan, is closely involved with the project on a day-to-day basis. Mr Gong is an instructor at the Institute and is the system manger for the project. He is responsible for supervising use of the system, for scheduling and supervising the monitors, and for liaison with Softwords. The course managers for the project are Mr Sen, head of ECNU's Computer Science Department, and Mr Lu of the Institute of Modern Educational Technology. The course managers provide assistance to students working through the

course, mark student assignments and provide independent off-line tests on the course content. Two Ph.D. students and one Masters student within the Institute are the monitors for the course. They assist in running the laboratory, answering student questions and marking assignments.

CBT and networked computers are of great interest to the Institute of Modern Educational Technology because of the need to upgrade teachers in China and to provide sufficient teacher training to keep up with the demands of the population. CBT offers a possible solution to the major problems Chinese educators face in providing teacher training. More people can be reached through computer networks than through regular university lectures because the delivery sites can be made available for long hours and can be set up at convenient locations. In addition, CBT allows a few skilled people to spread their knowledge far more widely than is possible using traditional methods of instruction.

7. FIRST TRIP TO ECNU

In order to establish the first courseware creation and delivery site at East China Normal University, and so to accomplish the first goal of Project 'Clear Skies', two of the authors (Sarret Smit and Neil Koorland) travelled to Shanghai in November 1985. They spent two weeks at the Institute of Modern Educational Technology, setting up the courseware delivery system and introducing members of both the Institute and the Computer Science Department to the hardware, the operating system and the courseware.

8. SYSTEM CONFIGURATION

The hardware system used in Shanghai is a local area network produced by Meridian Technologies of Toronto and distributed by Burroughs Canada. This network consists of a fileserver and a number of ICON workstations running the QNX operating system on a 2.5 M bits/sec token ring called the ARCNET. The ICON network is the most widely used of two systems approved by the Ontario Ministry of Education for use in Ontario schools and is well suited to a CBT environment.

In November 1985 three ICON workstations and one fileserver were installed at the Institute of Modern Educational Technology to deliver the courseware to first-year computer science and other students and for CBT development at the Institute using NATAL as the authoring language. The installation of the system at the Institute in November 1985 was greeted with tremendous enthusiasm by faculty and graduate students in the Institute, who are faced with a distinct lack of computing facilities. Prior to its installation the Institute was only able to produce CBT material in an *ad hoc* fashion, with limited hardware and inadequate course authoring tools.

The courseware being used at ECNU is the same as that in use at North Island College, adapted appropriately for use in China. Since the students are initially taking the course in English, most of the adaptation was in modifying the course content to deal with the nuances of a different Pascal compiler. As with the VAX, PDP/11 and Optimum versions of the course, porting the NATAL code and data to the ICON was very straightforward. In addition to teaching computer science, it will also be used as a case study by the Institute of Modern Educational Technology to assess the effectiveness of Canadian CBT strategies in the Chinese educational context. If deemed successful, it will provide the basis for future CBT courses developed by the Institute.

9. NOVEMBER 1985 TO FEBRUARY 1986

The Computer Science, Electrical Engineering and Library Science Departments and the Institute of Modern Educational Technology began their evaluations of the course during November and December. Both the Institute and the Department of Computer Science have decided to offer it for credit. The second semester began on 19 February 1986 and, at that time, ten Institute students started taking it as an optional credit course.

The Computer Science Department teaches Pascal programming during the fall semester, and first-year computer science students will begin taking the CBT course as a compulsory credit course in October 1986. It is not yet known whether students from other departments will take the course, as those departments are still completing their evaluations. A maximum of 75 students can take it during any semester.

Once the evaluations have been completed it is anticipated that students from the Institute of Modern Educational Technology and from the Electrical Engineering, Library Science and Computer Science Departments will all take the course for credit. This will give Softwords the opportunity to evaluate student progress in China, and to obtain feedback from the Institute regarding reactions of students and faculty to this trial of learning computer science through CBT.

10. SECOND TRIP TO ECNU

In early March, when the second trip was made by Softwords' staff to ECNU, seven ICON workstations and a second fileserver were installed. The hardware has been set up as two independent networks, each consisting of five ICONS, one fileserver, and a printer. It is envisaged that a third network delivering CBT will be located in downtown Shanghai and connected to the ones on the ECNU campus via a telephone or microwave link. Eventually such networks will be located in a number of places across China, with each network being able to receive new courses and updates via satellite.

The Softwords' staff stayed at ECNU for two weeks to set up the second courseware delivery system, which has been established in the same building as the first, and to implement a process for evaluating the courseware at ECNU.

To compare student progress at ECNU with that at North Island College, Softwords will be collecting weekly reports from all CBT students at ECNU to obtain information concerning difficulties experienced in using the course, length of time spent on the Units and the assignments, the part played by print materials and the tutor. Softwords will also collect weekly reports from the tutors about the student problems that are asked to deal with. Softwords' student tracking program will also provide useful data about learning computer science by CBT within the Chinese educational system.

11. ECNU'S FUTURE PLANS

Members of the Institute feel that setting up the 'Clear Skies' project at ECNU may be the first stage of a CBT teacher training program in Shanghai. If student progress in the course offered by CBT is favourable, compared to their progress through similar courses already offered by ECNU, the university will move one of the courseware delivery systems to a more distant area on campus. This would be a preparatory step toward setting up remote delivery of the courseware. Once established, such remote delivery of the course would primarily be offered by ECNU to upgrade high-school teachers of computer science.

12. CONCLUSION

Numerous studies and meta-studies have demonstrated that CBT can lead to productivity gains of 20–30%. Although the techniques of CBT are well documented, the rate of implementation of CBT has been slower than might be expected, given the obvious economic advantages. For Softwords, Project 'Clear Skies' represents ongoing research into the domains of cognition and CBT implementation engineering. The latter is a new domain which is only slowly begin to establish some basic principles. There are major differences between Shanghai and Vancouver Island, of course, but these may help clarify what are common implementation difficulties.

To date, ten substantive factors have been identified that can affect the implementation process. Nine of these factors have been identified as relevant during Project 'Clear Skies' and, to date, been dealt with successfully.

(1) In North America, job-security appears to be the major factor slowing implementation. If management does not establish an environment where productivity gains from CBT are translated into increased activity for the instructional staff, then CBT is often seen as a threat to employment and/or growth of the division. Under these circumstances, CBT will be resisted and, if implemented, may well be sabotaged. In China, there is greater employment security and to date CBT has not been seen as a threat, given the enormity of the educational tasks to be accomplished.

(2) The provision of support at all administrative levels appears to be a common factor at all successful implementation sites. Staff, managers and senior administration must all have educated and realistic expectations about the role of CBT in their institution. They must look on the process as a long-term one and must see that the pattern of implementation will be unique to the structure, levels of expertise and culture of their institution. Far too often initial support for CBT comes from only one level at the institution and the first difficulties, which are almost inevitable in one form or another under these circumstances, lead to the demise of the project.

(3) An interesting factor which this project has helped clarify for us is the distinction between Open Learning and traditional education systems. It appears that Open Learning systems have greater adaptability for some of the advantages of CBT than do traditional systems. At North Island College the initial target for the trials was twenty students. In fact, about that many were enrolled in late 1984. However, as news of the course spread, a regular increase in enrolment took place every week. This would not have been possible at a traditional institution. Since Open Learning systems, in general, provide education on an individualised, self-paced, exploratory basis, they lack the administrative hindrances which can retard the implementation of CBT in institutions where terms are of fixed length, progress of all students is standardised and the lecture sequence determines the pacing of information distribution, assignment completion and final grading. In addition, Open Learning Systems have as a goal the distribution of education to students rather than the collection of students into a single location for administrative ease.

(4) At the moment, North American high technology has a certain cachet in China. Normally one would expect that the difference in cultural environments would be an important factor in such an experimental development. The Department of National Defense, for example, has a strong preference for in-house training because of the impacts of their specific cultural environment on many aspects of training. At the moment, NATAL courseware in China is being presented in English. We will be interested to see the results of future research into Chinese language courseware and courseware written in English by the Chinese researchers.

(5) The development of a team structure for the production and modification of CBT materials is often difficult in traditional North American educational systems, which place a high value on individual research and teaching activities. Again, the Open Learning system at North Island College provides useful models for team development while the Chinese social structure lends itself to team activity. Canadian university researchers connected with the project may have difficulty being properly 'rewarded' for their role in a project with such diffuse lines of authority, however. One of the goals of management in CBT implementation must be to ensure that reward systems are modified to meet the requirements of team development of materials.

(6) Those who are opposed to or fearful of CBT are often unwilling to express their opposition openly. One of the more common modes of indirect protest is to concentrate on the 'next-generation tools' that are just around the corner. This avoids the need for actually implementing CBT while still presenting a façade of strong interest. Some administrators develop criteria lists that are self-contradicting. They will ask for state-of-the-art features and also proven market acceptance. The Chinese, on the other hand, are eager to work with existing technology, while the North Island College experience (VAX to Optimum to Tandy) demonstrates that courseware can be implemented and then modified to work on newer hardware as that becomes market proven.

(7) One factor often ignored in implementations is the rate of maintenance. This is largely based on two factors: the volatility of the underlying content and the range of learner skills. Some courses are inexpensive to implement but costly to maintain. Some work well with a trial group but then have to be modified when widely distributed. Courseware for this project has been carefully selected to minimise the rate of maintenance.

(8) For the educational world the questions of cost-sharing are of prime importance. Proper mechanisms have not yet been established for sharing the costs of producing CBT materials. The economic advantages

of CBT will only be full realized when costs are shared, certainly within provinces and hopefully within the entire nation. To do this, the kinds of standards that NATAL was originally designed to provide are essential. However, the territoriality of existing educational institutions acts as a major barrier to cost-sharing. To date, only Ontario and Quebec have established major policies on implementation and their positions, as one might fear, are contradictory.

(9) In some implementation the course data is private and has corporate value. This negates the possibility of cost-sharing or cost-recovery and imposes security requirements not common to the bulk of courseware. This was not a factor in Project 'Clear Skies' although it was necessary to obtain a security release to ship NATAL to China.

(10) When initially facing the question of CBT, few administrators think of portability. They are either tied into an existing system or they are sufficiently confused by the range of offerings that they want to come to a clear, single decision. In time, however, they come to learn about portability: their hardware base changes, they want to move a proven course to a different division, they have staff who want to work at home, etc. The courseware in this project is already portable across a range of UNIX-based machines. Current developments will establish an MS-DOS migration path using a NATAL interpreter. This will permit all courseware involved to be delivered on the widest possible rage of hardware.

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