Interactive teaching practices in small class sizes while Cutting into the high cost of education

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Abstract: The constant increase in the cost of higher education; recent market demands for computer specialists; lack of expertise in offering technology-oriented courses; and a new class of non-traditional adult students, combined with the constant pressure to maintain small class sizes call for new teaching practices. Furthermore, it has been proven than people's learning styles differ; most students absorb and retain visual material more readily than other types of material, but the world is full of ear-learners and those who learn by physical practice. The average learner retains about 20% of what is heard, 40% of what is seen and heard, and 75% of what is seen, heard, and experienced. A traditional classroom setting mainly offers seeing and hearing practices; print- or video-based distance study breaks the classroom boundary but offers the same teaching practices.

Recent marriage between computation and communication technologies offers a natural solution to these issues: Advances in computer technology allow information to be presented in many different ways (multimedia); hence, interactive computer courses offer all three modes of learning. Advances in communication technology allow the information to be available anytime and anywhere. The marriage between the two allows a higher degree of accessibility and offers various learning modes beyond the traditional time and space limitations.

This paper addresses our effort and experience in developing a computer organization course using multimedia technology. In addition, it discusses some future changes in developing modular courses in computer science/engineering curricula.

Keywords: *Interactive-teaching, multimedia, computer-organization, CD-ROM*

4. Introduction

In recent years a concern has been raised that the higher education system as a whole and the so-called research-oriented universities in particular have forgotten their mission to effectively prepare students for their perspective roles in the **real world**. In an effort to rectify this concern, the College of Engineering at the Pennsylvania State University, like many other large universities, launched a campaign to improve effective classroom teaching. However, in the information super-highway era when the technology is advancing so rapidly, effective teaching is not the only challenge to be resolved. How to keep students, curriculums, and working class people up-to-date is becoming even a more challenging task. Today's curriculums are becoming more and more demanding and courses are becoming more and more complex and voluminous. Solutions as such — Expanding the baccalaureate degree, intensifying the high school curriculums, etc. should be studied in length and should be measured based on their economical impact. As a practical solution we suggest to: i) revise the old-fashioned teaching practices to encourage, motivate, and attract potential students despite of their physical, geographical, and economical handicaps to the universities and colleges, and ii) develop new flexible and cost effective techniques to involve students while improving their learning ability. This suggests distance as well as on-campus education and a teaching platform that motivates interactivity, hands-on projects, and flexibility.

Research has also shown that people's learning styles differ; most students absorb and retain visual material more readily than other kinds, but the world is full of **ear-learners** and those who learn by physical practice. The average learner retains about 20% of what is heard, 40% of what is seen and heard, and 75% of what is seen, heard, and done (Reisman and Carr 1991; Yager 1991). A traditional classroom mainly offers seeing and hearing; print- or video-based distance study does the same — **passive teaching techniques**; but interactive computer courses offer all three modes of learning. As Edward I. Vockell noted in an article on instructional principles (Vockell 1990), "One of the major strengths of the computer is that it can present the same information in many different ways."

The advantages of interactive computer teaching are flexibility, lower cost, and active learning. While Liberal Arts disciplines are already making use of interactive computer courses, no sequence of university-level computer science and engineering courses exists. Interactive courses are particularly effective in fields such as engineering, science, architecture, and archaeology, where hands-on manipulation of elements in a design or research project can be simulated on a computer. A good example, funded by the National Science Foundation, is an archaeology course created by Kathryn Cruz-Uribe of Northern Arizona University and Barbara Mills of the University of Arizona. According to Ms. Cruz-Uribe, the program's major benefit is that it allows students to work with artifacts that would be too fragile to handle or unavailable to them in real life (*Chronicle of Higher Education* 1993). On-screen assembly and analysis is equally appropriate in computer and electrical engineering.

In November 1993, an informal poll of AACIS (the American Association for Collegiate Independent Study) was taken. Questions concerned costs of developing multimedia computer-based courses for distance learners' potential enrollments based upon student interest, and availability of hardware among the student population. The response was meager: most universities are not yet developing their own interactive courses, although they expressed interest in buying packages produced by somebody else.

This paper is intended to discuss our effort and experience in developing a multimedia computer organization course. In addition, it overviews our future efforts in this direction. Section 2 overviews some of the efforts in developing multimedia courses. Section 3 addresses our multimedia course. Section 4 discusses our experiences in offering such a new teaching practice in traditional classrooms, and finally, section 5 concludes the paper and highlights our future efforts in this direction.

5. The literature review

A number of efforts in various universities such as the University of Minnesota, University of Illinois, University of Texas at Arlington, Purdue University, etc., are underway to introduce multimedia capability in engineering courses (Hoffman et al. 1993; Joshi et al. 1995; Joshua and Scuse 1995). The University of Maryland at College Park has developed an interactive program on Far Eastern culture and geography called "Hyperties"; the Graduate School of the U.S. Department of Agriculture offers four courses to teach teachers how to use multimedia. The University of Texas at Austin has been active in developing interactive courseware: individual lessons in "American Civilization" and a complete geography course ("The Geographer's Craft") are currently underway. Tulane University is developing a CD-ROM course on the Civil War called "Fort Sumter" and an archaeology course called "Pompeii." In addition, A number of interactive history and archaeology courses are commercially available from such publishers as D.C. Heath, Voyager Company of New York, and Scientific American, but we are unaware of any commercially produced engineering courses in the area of computer organization/architecture. There are, at present, no multimedia courses in the United States that are designed as a series of interrelated modules in computer science and engineering. Apple's "Hypercard/Quicktime" software has been used to create "Laboratory Introduction to Embedded Control" at the Rensselaer Polytechnic Institute, the only program that comes close (Borkowski et al. 1993).

Traditional classroom based and distance education will benefit greatly from interactive technology in the future. Interactive computer-based courses offers many attractive advantages such as (Barbard 1992; Bea 1990; Bruder 1993; Miller 1990; Vockell 1990; Reisman and Carr 1991):

- **Reduced learning time:** Over the past 15 years, nearly three dozen studies have been published that show that interactive courses reduce learning time requirements by fully 50%. Self-pacing or individualized instruction, which allows students to fast-forward through areas they have already mastered and spend more time on their weak spots, probably accounts for most of this, but another factor is immediate reinforcement and review.
- **Lower cost:** The design of interactive computer courses (that is, the front-end investment) is much higher than the cost of designing a print-based course, but replication and delivery of the course is much lower. This, in turn, means that corporations or government institutions that pay for their employees' education find interactive courses more cost-effective than print-based or video-based courses.
- **Consistent teaching quality:** Different sessions of the very same course will be presented the same to the audience**.**
- **Self-pacing, Privacy, and flexibility:** This is particularly important to adult students. Interactive computer courses make the classrooms more accessible to each individual learner and bring the classrooms to the workplaces and privacy of the homes. Privacy reassures those who have been out of the classroom for many years and feel awkward about asking "stupid questions" in front of others. Time flexibility is essential to adults with full-time jobs and/or families.
- **Better retention and more active learning than in the classroom:** Improved test scores have ranged from 25% higher in a study of Spectrum

Interactive/National Education Corporation to a staggering 300% higher in a remedial high school class in Bethel Park, PA. One contributing factor is that teachers can monitor and communicate with many more students at a time than they can in the traditional classroom, especially using the network systems. Another is that interactive learning requires frequent and regular input from the student; it is impossible for students to doze through lectures, buy other students' notes, and cram for exams at the last minute — all of which are inefficient learning strategies.

- **Lack of expertise:** Interactive computer based courses will help to solve the budgetary issues and lack of expertise in teaching technology and higher-level courses. Specially, small colleges could incorporate and offer these courses as part of their curriculum through the network.

All of these factors lead to increased motivation and "investment" in learning. Perhaps the major advantage of computer based interactive teaching method over traditional teaching practice, however, is:

- **Increased access to education:** Education can be delivered anywhere and anytime by satellite, video, computer, e-mail, or print. It offers anyone a chance to take a course, whether there is a nearby institution of learning or not. Places as disparate as prisons, Navy submarines, and oil-company stations in the Saudi Arabian desert are full of distance learners pursuing Bachelor's and even Master's degrees. The **disabled** and people who are geographically tied to their jobs benefit especially from computer courses. While these courses will be delivered by CD-ROM, they may also be delivered over computer networks. A course could be downloaded to a server or individual hard drive in cases where CD-ROM players are unavailable.

It should be noted that this paper neither questions the effect of traditional teaching practices nor suggests distance education as an alternative to the traditional on campus teaching environment. However, we believe that advances in technology can be used to: i) improve student's learning ability in the traditional classroom setting and, ii) facilitate access to the courses, specially for those who do not have access to the classes.

3. Design of Project

Originally, three undergraduate courses and one graduate course were planned to be adapted to CD-ROM. Each course consists of modules on separate topics; these are interrelated with other modules over the entire series of courses. Some modules require prior knowledge; if the student does not have this background, he/she can work through a module from an earlier course before reentering the current course. If the student has already mastered the material in a module, he/she can choose a module from a more advanced course. **Self-assessment interactive questions** appear at the end of each module. Each course contains homework assignments, **design challenge projects**, and exams. This "mix-and-match" design will allow students — specially those who do not have strong background in this area, and/or those who do not have access to the classrooms (Distant Education) — to customize courses for their own needs while earning academic credits (certificate degree).

Initially a junior-level computer organization course was chosen as the target. A team of ten people was involved during different phases of the project. The whole project took about three and one half years to develop. Finally, though it is very hard to figure out the total cost, however, roughly it costs about $110,000 to $130,000 to finish the project. A preliminary interactive version of the course was offered in spring 1996 and made available over the MAC network at our campus. Summer 1997 as a final test, the new version of the course was offered to a limited number of students and Fall 1998, the complete version of the course was offered to two classes each with about seventy students.

Initial design meetings addressed the goals and objectives of the course, and the construction of test questions and design challenges to measure student attainment of the goals and objectives. In addition, issues such as presentation and sequencing of content; use of media, animation, and interactivity; and provision of help to the student in the form of flexible navigation, a glossary, hypertext definitions for unfamiliar terms, a Help module were laid out in detail. Figure 1 shows the course contents and general lay out of each frame. The target course was a collection of fourteen modules. The course was designed to be interactive and flexible for the students, who can navigate freely through the program. Students can quickly choose a different main topic (module) or sub-topic, and can choose sub-sub topics just as quickly.

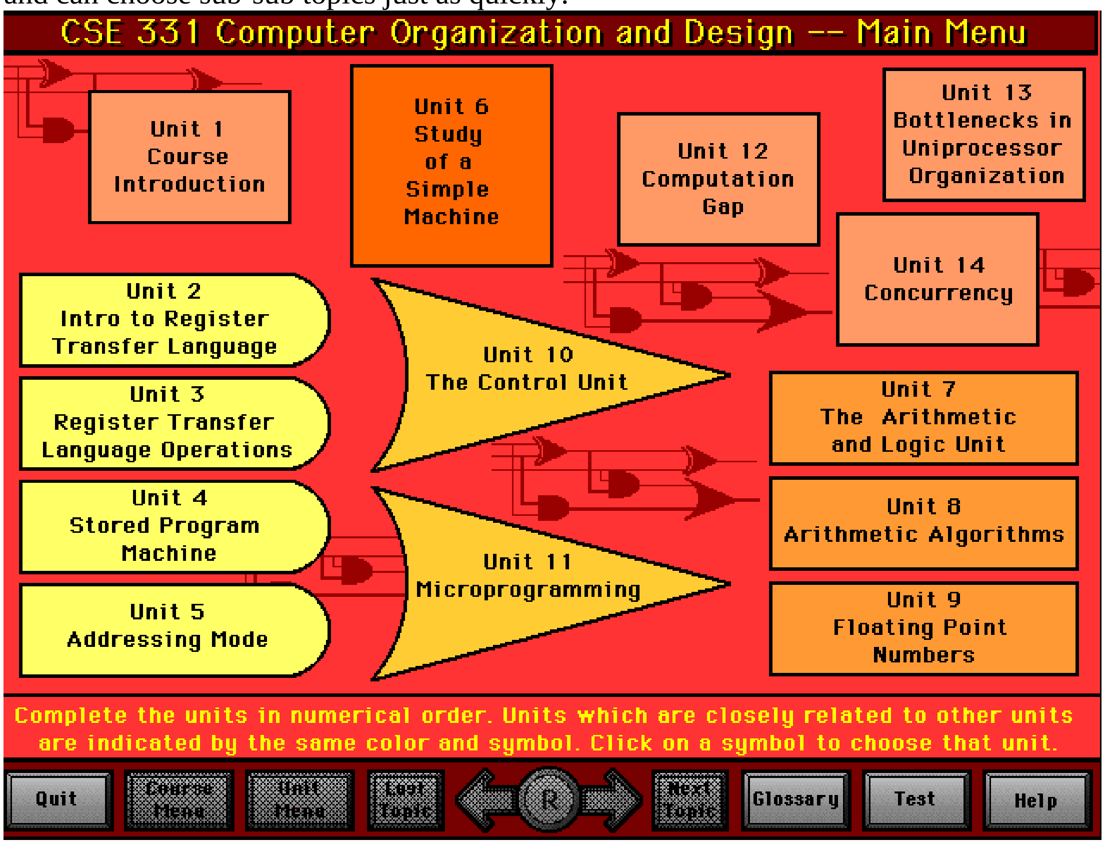


Figure 1: Table of contents and general frame design.

Another broad design issue was student self-assessment that took the form of questions at the end of each module. Self-assessment questions took a variety of forms, including **dragable** or movable objects, multiple choice, and short answers. Provision was made to allow student to respond to **hints** in order to compile an answer.

The course employed a multimedia approach. Graphics and animation were used to demonstrate such concepts as the exchange and conversion of data among components of the computer. Audio played a key role by providing narration and **focusing** comments during data animations; reinforcing comments and additional information for charts, diagrams, text screens; and as an additional informational channel for learners in general. Text, sometimes reinforced by audio, carried part of the presentation of facts, statistics, and concepts.

Many times, the presentation makes use of audio narration that is timed so as to coincide with the presentation of screen elements. Rather than presenting an entire screen full of information all at once, which is difficult for a student to focus on, we presented the screen element by element and the narration discussed each element in turn. One good example of this is the screen entitled, **Course Introduction: Block Diagram of a Basic Computer**, one of the very early screens in the program (figure 2). The course describes the four basic components of a computer (input unit, output unit, memory unit, and central processing unit) and, as each unit is named, that part of the diagram appears on the screen. The central processing unit is then shown dividing into two other units, the control unit and the arithmetic logic unit, while this division is explained in audio. The student may now click the **REPLAY (R)** button to hear the explanation again or click **NEXT Topic** to see the next stage of the diagram. At the next stage, solid black arrows are added to the screen — data paths. Again, the student may replay this explanation or, by clicking **LAST Topic**, may see the first stage of the diagram again. The third stage of the diagram involves the placement and discussion of control paths between the units. The last stage adds the information and result labels to the screen while the audio ties together what has been learned: **a computer is a system whose components work together to accept and process information and then deliver a result**. Once the diagram is complete, it becomes a menu for further study. The student may click any of the computer units to learn more about that unit. There has been a strong use of **hypertext** throughout the package (hypertexts on the screen are colored as gray in order to be easily identified). Clicking on one of these terms brings up a new screen with the definition of the word.

As instructionally supportive as audio and hypertext are to the course, perhaps the best use of multimedia is that of animation. The content of this course is at times abstract and difficult to visualize; animation is one tool whereby we can make the abstract very concrete and the visualization clean and straightforward. Animation will most often be used to depict the movement and transformation of digital values within the computer. This animation will occur in stages, accompanied by narration and visual screen cues that explain and highlight what is going on as the computer processes information. One of the simpler examples of our use of animation in this fashion is the series of screens entitled, **Flow of the Control** (Figure 3), which is an attempt to demonstrate the difference between the **macro** and **micro** programming levels.

The **second stage** of design, the actual programming (and the most time consuming part) used an authoring package called "Macromedia DIRECTOR to convert the course contents. As each module was completed, it was reviewed several times for academic content.

The **third stage** of design involved writing documentation. A manual was developed to show how the audience could use the package.

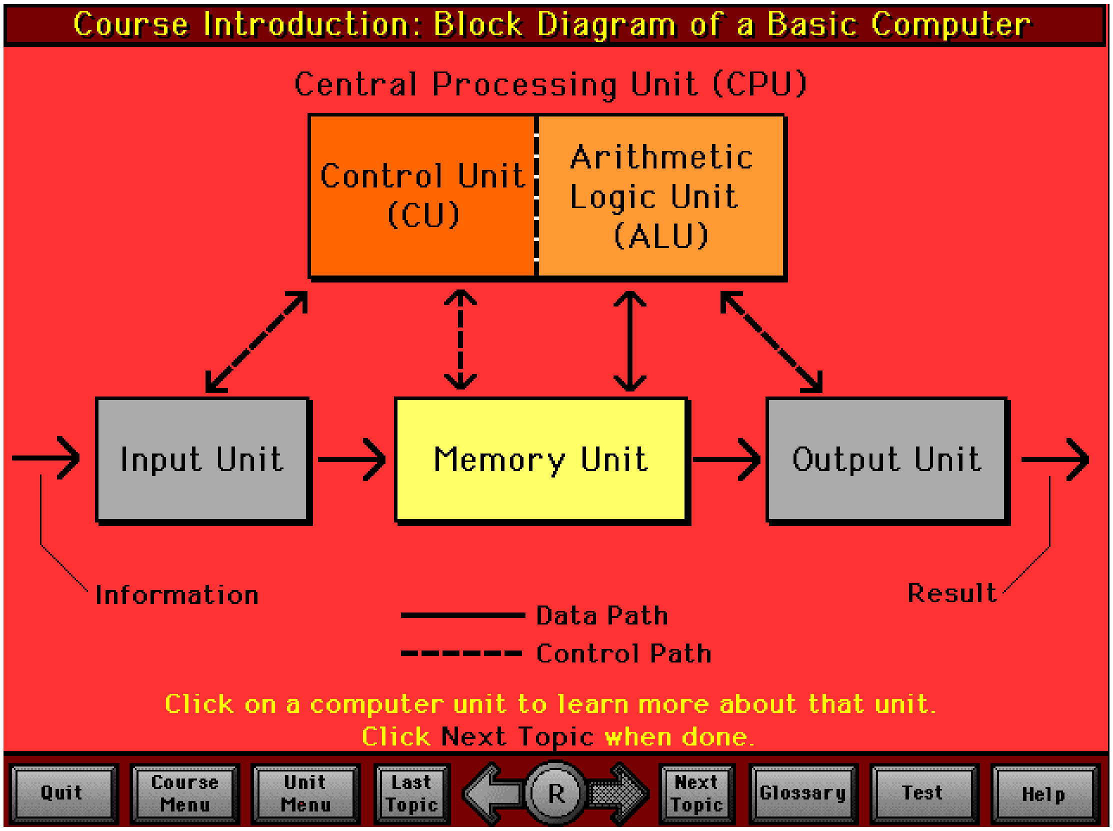


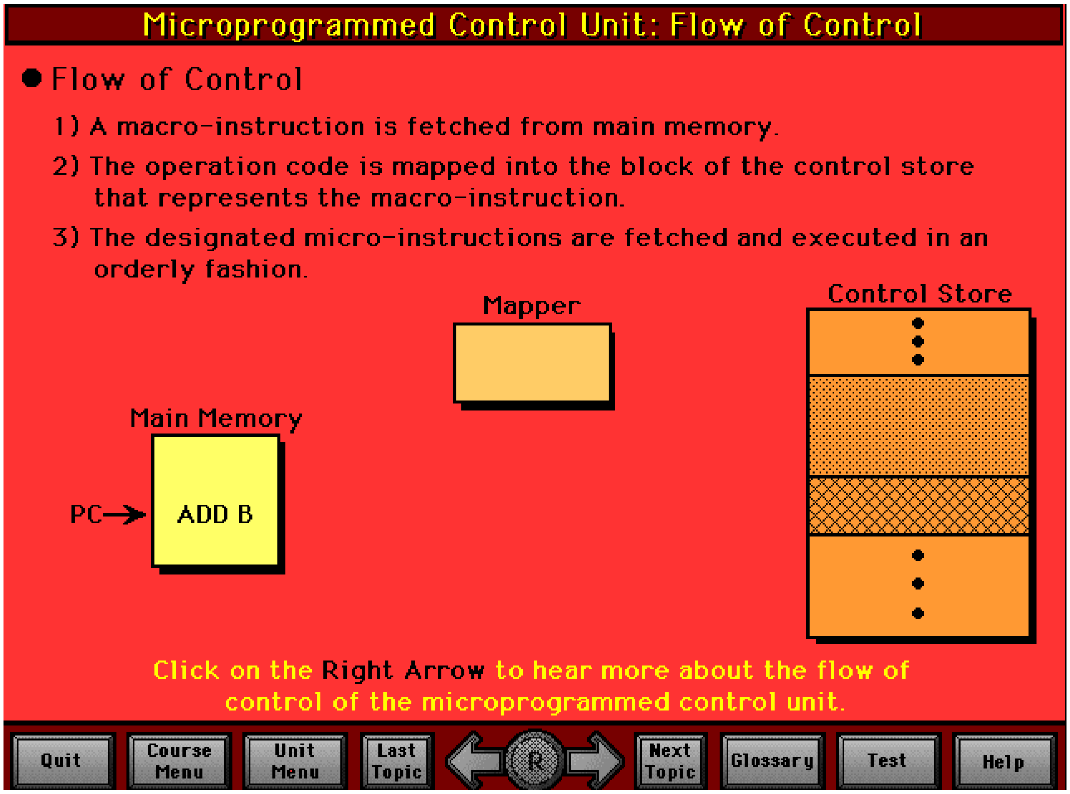
Figure 2: A menu for further study.

Originally, it was decided to design the course on dual platforms and through the available internets so that the widest possible audience could be reached. However, due to budgetary constraints, Master CD-ROM was produced in MAC formats. Manufacturing the master CD-ROMS and having copies pressed by a commercial house was the **fourth stage** of the project. Marketing and communication will be the last step.

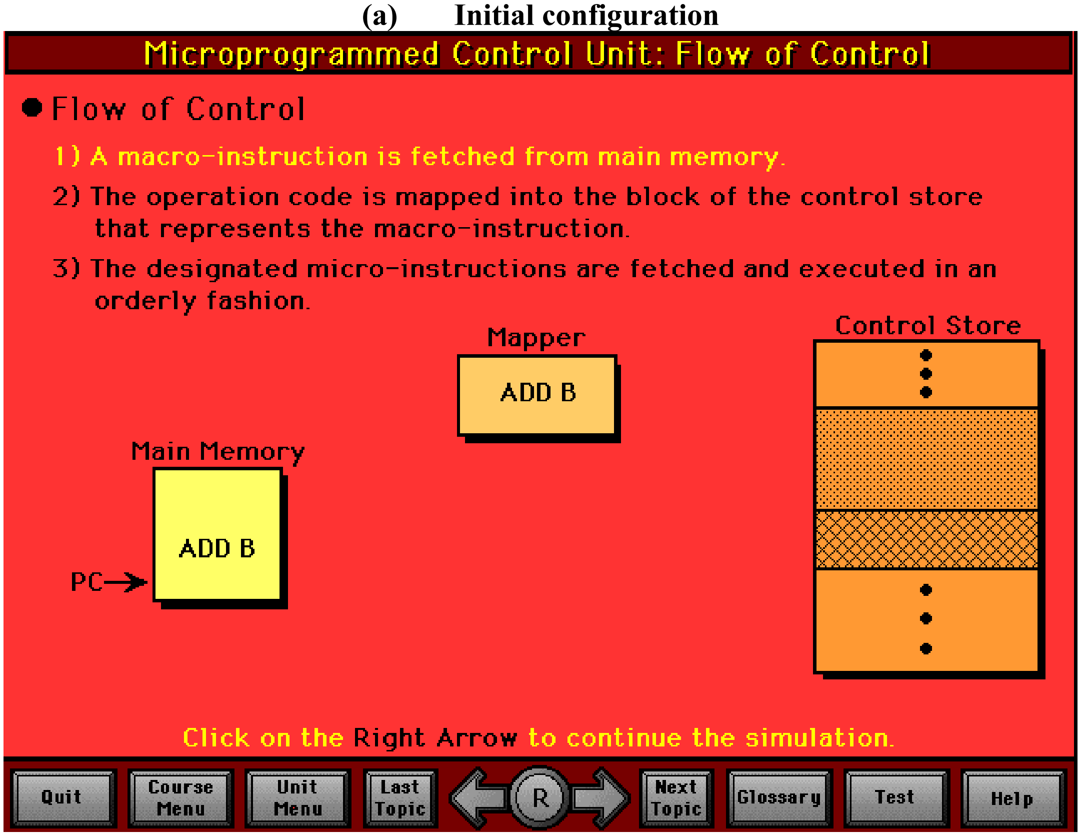
4. Our Practical Experience

Early in summer 1998, due to the lack of personnel, the issue of teaching two sections of our junior level computer organization course was raised. The multimedia version of the course was put on the Macnet at our campus and two labs were designated for the course. The courses were supervised by a faculty member and a teaching assistant was chosen for each section. The intention was to improve active learning by reversing our traditional teaching practices. Rather than students passively attending the course, they had to review a designated portion of the course prior to each class, and then they were expected to bring their questions to class. To monitor students progress, a quiz was intended to cover the weekly portion of the course that was learned and discussed in the class.

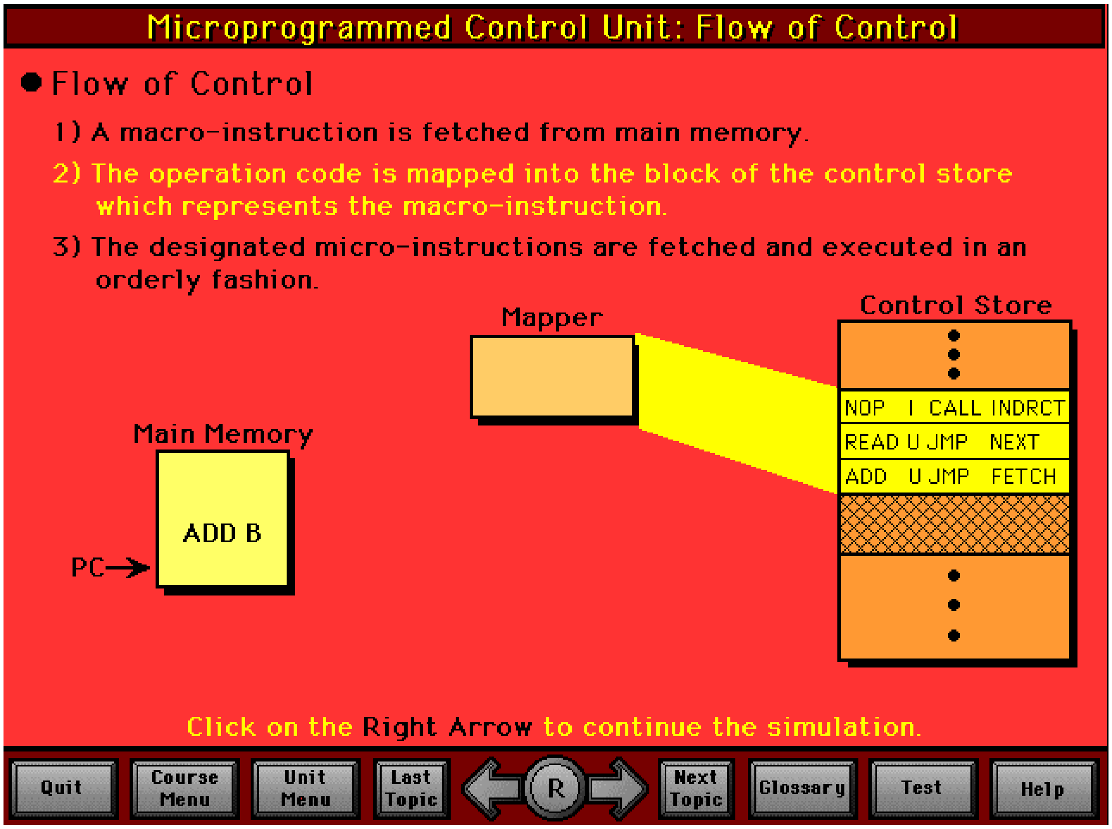
Although, students appreciated the flexibility and accessibility of the course, in general, students did not respond positively to the new course-offering. This could be attributed to many factors including:



(a) Initial configuration



(b) Macro instruction is fetched



(c) Macro instruction is mapped

Figure 3: Several snapshots of a sample animation.

- Our reactive response to the crisis (lack of personnel),
- It takes time to adapt to change, and as in similar circumstances, it should be expected that students would resist this change since they are accustomed to a more traditional teacher-centered environment,
- Lack of experience in offering multimedia courses,
- Inability of the teaching assistant to motivate students' participation and to articulate class discussion,
- Relatively large class sizes.

Although, it is unrealistic to draw a decisive conclusion, relative to traditional offerings of the same course, average performance of the students in both classes improved.

5. Future efforts

At present, we are seeking financial support for the test offering of this course in classes with limited enrollment. In addition, several core courses in the computer science/engineering curriculum were designated for multimedia offering to graduate students with insufficient background (those who intend to switch to the computer science/engineering discipline) and/or to re-train adult students.

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