Abstract. This paper describes the development of a high-quality laboratory for computer science majors over the last decade and plans for its continued development. We start with the historical background and then describe the current situation that involves moving the introductory programming course to Unix workstations. This decision has resulted in many benefits and a few unanticipated problems. Finally, we speculate about future development and describe two possible scenarios: one evolutionary, based on continued adaptation of the original lab concept, and the other revolutionary, based on rethinking the underlying goals of the introductory CS curriculum.

1. Historical Background

After examining the original goals of the undergraduate lab and how these goals have evolved, we describe the hardware environment and structural organization of the lab. We conclude the section with a description of the computer based software developed to support the introductory programming course.

Goals of the Lab

At its inception in 1978, the laboratory was developed to support the first course for computer science majors, an introduction to problem solving and computer programming using a block-structured language [Adams 81]. One of the major objectives of the lab was to provide sufficient instruction and assistance on programming issues to permit:

- spending more time on conceptual issues in lectures,
- making a rather large final programming assignment feasible, and
- introducing software engineering issues and techniques in the course.

As it turned out, the lab had another very desirable function: providing valuable software engineering experience for upper division undergraduates. This resulted from the way the lab was organized and staffed, as discussed in the next section.

The original lab was used strictly for our introductory programming course. Since that time the lab has expanded to include all of the programming courses in the
undergraduate curriculum, shown in Table 1 in Section 2. This has resulted in some additional objectives:
- access to "bare" machines so that students can learn low level, interrupt-driven programming techniques,
- introduction of alternative programming paradigms (functional, object-oriented, logical) on powerful workstations,
- use of hypertext-like environments using high resolution graphics consoles,
- development of operating systems concepts on Unix PCs,
- use of document preparation software for laser printers, and
- introduction to parallel processing using Ada tasking on a multiprocessor Sequent computer.

These objectives have only been attained with respect to hardware, system software and classroom instruction. As of now, we have no CAI software to support any of these additional objectives. Some of the objectives, such as hypertext-like environments and document preparation software, have been attained simply by making the software available and letting the word spread amongst the students. They train themselves and share "secrets of the trade." In fact, they are becoming so accustomed to large, high resolution displays and laser printers that they often demand more infrastructure support than we can provide.

**Hardware and Organizational Structure**

The laboratory was conceived on the model of student newspapers -- i.e. it was to be operated and managed by undergraduates for the purpose of serving other undergraduates, but having the side effect of providing the operational/management staff with experience simulating an actual work environment. The enabling technology for this idea was the microcomputer, with relatively tractable software systems and maintenance issues. With the assistance of an Instructional Scientific Equipment Program (ISEP) grant from the NSF, the lab was begun in 1978 and equipped with Terak microcomputers.

For the first two years the lab was operated in a fashion that has now become rather traditional for microcomputer labs, except that all management, operation and maintenance was done by undergraduates under the general supervision of one faculty member. During this period, CAI material was obtained from the University of California at San Diego [Bowles 78] and installed by the staff, as discussed in more detail in the next section.

In the next stage of development, the staff undertook development of our own CAI material and a conversion to the next generation of microcomputers, the IBM PC. This was done with the aid of a Comprehensive Assistance for Undergraduate Education (CAUSE) grant from the NSF. In this stage, the undergraduate staff took considerably more responsibility for providing tutorial assistance, conducting lab tests, and maintaining a larger group of machines. Concomitantly, the responsibilities of the undergraduate managers increased. Perhaps the greatest problem during this stage was the