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Publication Date

1984-07-25

Peer reviewed

COMPUTER BASED LEARNING UNITS FOR SCIENCE
AND MATH FOR SECONDARY SCHOOLS

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Technical Report 234

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July 25, 1984

This paper describes a development, over approximately five years, of a highly interactive graphic set of computer based learning materials, primarily focusing on middle school and high school, and concerned with science topics, with a few mathematics issues included. The material was developed in two separate projects, one supported by the National Science Foundation, and one supported by the Fund for the Improvement of Postsecondary Education. The materials, although probably most useful in secondary schools, are usable with a wide range of users. Thus we believe that most of these modules will be usable in adult education situations too.

The general focus is on scientific activity, and on placing students in environments in which they must BEHAVE LIKE SCIENTISTS. These environments are friendly and helpful and do not allow a student to flounder forever. They offer specific help for students in trouble. The materials generally are in a mode which might be described as a "discovery" approach, but not all sections follow this approach.

While some of these materials have been previously described in papers from the Educational Technology Center at the University of California, Irvine, no complete description is currently in the literature. As the modules are now complete, and as we are considering the marketing possibilities, it seems desirable to offer such a description.

These interactive units are, as a group, unique. We argue that few other examples of computer based learning materials demonstrate more fully effective learning use of the computer, particularly the personal computer.

INTENDED ENVIRONMENTS

As already mentioned these science and mathematics learning aids,
while focusing on secondary schools, are intended for a wide range of types
of usage. The present section describes some of that usage. We have also
tested the units, particularly in formative evaluation stages followed by
improvement, in a number of these environments already. Testing in public
libraries has been particularly helpful, enabling us to improve
motivational aspects of the materials for a very wide audience.

The individual modules are designed to be self-standing. In a sense
they are like books for learning, assuming the student has no other
learning modes available. They do not require any previous acquaintance
with computers, any "computer literacy" background. Thus they will even
tell students to press return if necessary, after entering an answer, but
NOT repeat this phrase over and over for someone who is already familiar
with it, and therefore bored with hearing it.

Because these materials are selfcontained; as just indicated, they can
be used both in environments where teachers are present, such as the
typical school environment, and in environments where there are no
teachers, such as public libraries or homes. They are intended to be used
without any external "documentation" such as student manuals, books or
teacher guides. All the necessary steps to proceed are contained within
the computer dialogs themselves.

FORMAT

The modules are, for average student use, approximately one to two
hours in length. Although some variation occurs, many of the modules will
take most students about one and one half hours. Individual students,
because of their own different rate of progress, will move faster or slower
through the material.

The major learning units are broken up into smaller submodules,
usually lasting about 10-15 minutes. The programs totally contain about 20
hours of highly interactive graphic computer based learning material. As
indicated several projects were involved, funded by the National Science
Foundation and by the Fund for the Improvement for Post Seconday Education.
Total funding was about $400,000. Some of this funding was, however,
involved in building up the necessary underlying software, and so should
not be attributed directly to the development of the dialogs themselves.

The materials are coded in Pascal, using underlying software developed
at the Educational Technology Center. This software is used in all of our
materials. In a typical two hour module approximately 10,000 - 15,000
lines of Pascal code are involved. This figure is somewhat misleading as
compared with ordinary code figures, as computer based learning programs
contain a relatively high proportion of textual material. Strategies used
for this and other products from the Educational Technology Center are
described in our literature. Full references are available upon request.

The remainder of this paper consists of brief descriptions of each of
the modules involved. These modules are all available for inspection. We
stress that we are not describing hypothetical material here, but we are

describing developed and tested modules.

DESCRIPTION OF MODULES

Batteries and Bulbs

The student conducts an empirical investigation of electric circuits using batteries, bulbs and wires simulated on the computer. Concepts of current, circuit, resistance, and parallel and series arrangements are developed in a qualitative fashion. Technical terminology is not introduced until after the student has developed some intuition into the behavior of current electricity.

Truth About Tribbles

Based on Conway's game of Life, this module emphasizes the development of rules from experimental data. The student is the chief scientist on a space expedition and observes changing patterns on the surface of a strange planet. The goal is to develop rules for the appearance and disappearance of the patterns based on careful observations of evolving patterns.

Tribbles Families

In this module, the student, behaving like a scientist, performs experiments, collecting evidence and building a simple (Mendelian) model of genetic inheritence. The extra-terrestrial creatures are studied to determine their attributes, how to predict whether they will mate with each other, and what rules govern the characteristics of their offspring.

Distance

The module emphasizes the role of measurement in science. The initial activity involves simple measurements of distances by students. Concepts of experimental error, averages, scaling and measurement spread are developed from the data obtained by measurements. Alternative methods for measuring distance, such as timing the sound of voices or thunder, are illustrated using simulations.

Speed

A rich environment, containing balls projected from spring launchers, tunnels to partially hide the motions, scales of position, and digital clocks are used to develop conceptual understanding of velocity in both physical and mathematical terms. Students observe, compare and predict the motion of objects. The first three activities are qualitative, focusing on discrimination among the variables of position, distance, time, duration and speed. The next two activities involve quantitative measurements, and calculation of the ratio distance/time.

Space Lab

This module provides a "laboratory" for measuring properties such as mass, volume and density of some mysterious crystals obtained during a space mission. The student performs simulated experiments to obtain data on the crystals. The goal is to identify three crystals which consist of the same material. A major objective is to develop an understanding of the ratio mass/volume. A second objective is to develop the ability to discriminate between observations and inferences.

Graphing

The Graphing module introduces elementary concepts of drawing and reading graphs with one and two coordinate axes. The programs provide highly interactive tools for constructing graphs. Students use arrow keys on the keyboard to point to objects on the screen, and move them to appropriate points on axes of histograms and graphs. All activities begin with concrete activities and then develop more abstract notions of graphic representation. The concept of slope for straight line graphs is introduced and properties of non-linear graphs are touched upon.

Triangles

This module begins with classification of objects according to their attributes. The next activities introduce properties of triangles and lead students to a definition of a triangle as a closed figure having exactly three straight side. Later activities allow students to explore the relationships between sides and angles in triangles using simple animation. The terms right, acute, obtuse, scalene, isosceles and equilateral are introduced.

Whirly Bird

The Whirly Bird program is designed to be used along with a piece of physical equipment, the Whirly Bird of the SCIS elementary school science curriculum. The student is required to put together the devices, perform some experiments, and enter data into the computer. The program conducts a dialog with students, encouraging them to develop skills of identifying and controlling variables, and to construct a model system to meet a given specification.

Area

The student moves from an intuitive notion of area to a precise operational definition, the number of squares which cover a given figure. Extensive practice is available for those students having trouble applying the concept; students who grasp the idea more quickly go through the material more directly. Later activities connect the idea of counting squares with the common formulae for parallelograms and trinagles.

Heat

The student is engaged in a number of thought experiments about familiar experiences with heat (reading thermometers, observing temperature changes, mixing hot and cold water, melting ice, and boiling water). These exercises guide the student towards an understanding of the difference between the concepts of heat and temperature. The program has a conversational tone and allows free and unconstrained input.

Optics

Simple animation provides the student with a moveable flashlight, a plane mirror, an obstructing wall, and a target. The task is to strike the target with a beam of light by bouncing it off a mirror. The program guides the student step by step through acquiring evidence, considering alternative explanations, and constructing and refining hypotheses to explain the observations. Data obtained from variants of this task are

used to either support or refute various models of reflection which are proposed.