

Computer-Assisted Learning in Transportation Engineering Education

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Recent technological advances have led to microcomputers with enhanced capabilities at reduced costs. The introduction of cheap and powerful microcomputers has contributed to renewed interest in the use of computers as learning aids. The recent revival in the use of computer-assisted learning (CAL) is outlined in this paper. Three examples of transportation engineering applications of CAL are described and assessed. These applications are used to discuss important considerations in the development of CAL materials for use in different situations and to illustrate some of the benefits and limitations of this educational technology. The major objective of this paper is to stimulate interest in the appropriate use of CAL in transportation engineering education.

The use of digital computers as instructional aids began in the 1960s after the introduction of third-generation computers, which supported interactive (or conversational) computing. The computer was seen as an ideal tool for delivering the type of programmed instruction that was developed during the 1950s and implemented originally by using so-called teaching machines. Thus, the intellectual roots of early computer-assisted instruction (CAI) were in the programmed instruction movement of the 1950s.

Programmed instruction, which was based on Skinner's theories of learning, emphasized rote learning, immediate feedback, and reinforcement and allowed little individual adaptability. As a result, early CAI did not make good use of the computer's capabilities, and this is one of the major reasons for the initial dissatisfaction with the technology. Recent advances in computer technology have led to renewed interest in the use of computers in education and may provide a second chance for CAI (1). In particular, the reduced costs of microcomputers, coupled with enhanced capabilities (including color graphics, sound, and substantial random access memory), have stimulated the renewed interest in CAI.

The remainder of this paper is organized as follows. First, we review briefly the field of computer-assisted learning (CAL) as it exists today. (Computer-assisted learning is the term used in the remainder of this paper. This distinguishes the more recent applications of computers in the educational process from the computer-assisted instruction of the 1960s.) Second, we describe and examine three example transportation engineering applications of CAL that cover a range of the potential uses of CAL. In describing the sample applications we pay particular attention to the general structure and characteristics of the instructional materials to allow the reader to develop an appreciation of some general considerations in the development and use of CAL materials. Finally, we suggest some other potential applications of CAL in transportation engineering education. The major objective of this paper is to stimulate interest in the appropriate use of the CAL technology in transportation engineering education.

A brief description of some terminology used in this paper is useful. Courseware refers to course-related software. CAL material refers to computer software, worksheets, and user's manuals. A module is the smallest individual unit of CAL materials, typically of 15-25 min in duration. A packet is a collection of related modules.

CAL TODAY

Computers are used in education for many different purposes, including counseling and guidance, curriculum evaluation, testing, management of instruction, information retrieval, development of computer literacy, as well as for CAL (2-4). CAL, the focus of this paper, may be defined as the direct use of the computer in the presentation of instructional materials.

Today computers are employed as learning aids at all educational levels, ranging from preschool to college. CAL can be used for a variety of purposes, including drill and practice, tutorial, simulation or gaming, and problem-solving (5). The different modes of use can be classified conveniently according to whether the computer is primarily used as a medium or a tool. For example, the computer is primarily a tool when used as a computational aid in problem-solving. However, in the educational context, it is important that the student does not use the computer as a black box. Thus, in this context, the computer is used primarily as a computational tool and should also be a medium of instruction.

Despite the high level of recent interest in CAL the new technology is used relatively little at the college level, particularly in engineering. College-level applications described in the literature include physics (6), chemistry (7), economics, and business (8). Engineering applications tend to focus on structural analysis and design and electrical engineering and electronics. Cases in which computer software has been developed specifically for use in transportation engineering education are particularly hard to identify. One exception is the Transportation Teaching Package (TTP) developed at the Massachusetts Institute of Technology. In addition, some limited use has been made of industrial software in transportation engineering education. For example, Fisher (9) describes the use of the Interactive Graphics Transit Design Systems (IGTDS) package at Cornell University. However, in neither case is the computer used directly in the presentation of instructional material.

Computers are used extensively in the practice of transportation engineering and planning. Thus, the question that should be addressed is, Why not simply employ existing commercial and industrial software in educational programs? Two important reasons why the software used by practitioners is generally not suited for application in the educational context are as follows:

1. Computer programs (and accompanying documentation) used in practice appropriately assume that the user is already familiar with the basic principles and techniques. On the other hand, the objective of using the computer in education is to assist the student in learning the fundamentals.

2. Industrial and commercial software is very general and flexible, as indeed it should be. As a result, a potential user is often required to spend a large amount of time merely learning how to use a specific program. For example, the U.S. Department of Transportation offers a one-week training course to teach experienced transportation analysts how to

Table 1. Characteristics of sample CAL applications.

Name of Packet	General Description	Environment	User	Mode	Function of Computer
NETWORK	Illustrates network assignment techniques	Classroom	Instructor	Simulation	Medium
TRAFLOW	Reviews basic concepts of traffic stream flow	Computer laboratory	Individual student	Review and tutorial	Medium
UTP	Computational aid for urban transportation planning studies	Computer laboratory	Small group or individual student	Problem-solving	Tool

use the Urban Transportation Planning System (UTPS) package. In a college-level curriculum the primary emphasis should be on the study of the basic concepts, principles, and techniques, and little time should be devoted to the use of specific computer packages.

Thus, we need to examine the use of CAL in transportation engineering education and to develop CAL materials where appropriate.

APPLICATIONS OF CAL IN TRANSPORTATION ENGINEERING EDUCATION

The objectives of this section are to illustrate some potential uses and benefits of CAL in the context of transportation engineering topics and thereby to stimulate interest in the appropriate use of this technology in transportation engineering education. The summary information in Table 1 gives the three CAL examples described here. They cover a broad range of the possible applications. Two of the applications are designed for use by students in the computer laboratory environment, and the third application is designed for use in the classroom by the instructor. One of the computer laboratory applications is intended for drill, practice, and tutorial work; the other is designed as a computational aid. In two of the example applications the computer is used primarily as a medium; in the other application the computer is used primarily as a tool.

Example 1: NETWORK

The objective of the NETWORK packet is to aid students in learning network assignment techniques used in transportation systems planning. NETWORK is designed for in-classroom use by an instructor. The NETWORK packet currently consists of three modules, SPA, FHWA, and CREATE. SPA and FHWA demonstrate a particular shortest path-finding algorithm (10) and the Federal Highway Administration's iterative assignment technique (11), respectively. The third module, CREATE, assists the instructor in preparing example networks.

Features

The computer can be used in the classroom to display time-dependent phenomena or to illustrate three-dimensional objects or processes. The SPA and FHWA modules are based on the notion that, by considering the steps in an iterative calculation as being steps through time, one can employ the computer in the classroom to demonstrate iterative solution techniques. Because the phenomenon we are studying in this case has significant spatial properties, the use of computer graphics to display the results after each iteration is particularly effective. The computer also gives us the ability to demonstrate the answer to what-if questions. For example, What happens if a particular link is removed from the network? Furthermore, the computer display provides a dynamic quality that is hard to

replicate, even with a series of viewgraph overlays. Thus, the computer can be an extremely useful device in demonstrating iterative solution techniques or algorithms.

In the SPA module computer graphics are used to further improve the module as a teaching aid by careful integration of graphical and numerical representations of the solution procedure. Figure 1 shows the layout of the computer monitor screen for the SPA module and indicates how the mathematical and graphical displays are integrated at each step of the solution procedure. That is, we integrate a graphical representation of the development of the shortest path tree, and the computations undertaken at each step and the contents of the various arrays are displayed.

When CAL materials are intended for use by instructors as in-classroom instructional aids, the instructor's role must not be to simply turn the equipment on and off. Two specific guidelines follow from this observation. First, the instructor should be able to control the detail and the tempo of the display. For example, the SPA and FHWA modules allow the instructor to select either intermediate display of calculations or display of final results only. Furthermore, if the instructor chooses intermediate display of calculations, three different tempos are available--slow or fast fixed time display and user-controlled time display.

A second guideline that follows from the need to make the instructor an integral part of the lesson is that the module should be designed to allow (and encourage) the instructor to interact with the students. That is, to provide the instructor with a speed control is not sufficient. As opposed to CAL modules to be used by students in the computer laboratory environment, in-classroom instructional aids need not be completely self-explanatory. Thus, the instructor has the opportunity to interact with the students. In this way the CAL module functions as an instructor's aid.

One of the important benefits normally associated with CAL is that the student is an active participant in the learning process (12). However, in the case of in-classroom courseware, a specific mechanism, such as the use of worksheets, is needed to encourage student involvement, otherwise the use of modules like SPA and FHWA could be detrimental to learning.

Assessment

The students generally reacted favorably to the NETWORK packet. Only one-sixth of the respondents to a questionnaire agreed with the statement that CAL has little use in the classroom environment. However, one-third agreed with the statement that CAL modules should be used in the computer laboratory environment but not in the classroom. Most of the students thought that the NETWORK packet does not obstruct instructor-student interaction nor render the instructor redundant.

Based on the responses to the questionnaire and the instructor's experience, some general guidelines

Figure 1. Screen layout and integration of graphical and mathematical representations in the SPA module.

Display of Complete Network	A	Display of "Current" Shortest Path Tree	B
Record Keeping*	C	Calculations/ Decision-Making **	D

- STEP 1: display example network (A)
 - STEP 2: display initial status of arrays (C) and the origin node (B)
 - STEP 3: display calculations undertaken to select the arc to be included next in the tree (D)
 - STEP 4: show selection of arc to be included (D)
 - STEP 5: show the updating of the arrays (C) (mathematics), and show the updating of the "current" tree (B) (graphics)
 - STEP 6: repeat steps 3 through 5 until shortest path tree is complete
- * - display of contents of arrays used in shortest path tree calculations
- ** - display of the computations used to select the arc to be included next in the shortest path tree

can be formulated regarding classroom use of CAL materials. First, the CAL presentation should occupy no more than approximately one-half of the lesson. This allows the instructor adequate time to introduce the subject matter, motivate student interest in the topic, and answer questions prompted by the CAL presentation.

Second, the development of good worksheets is important to the successful use of CAL in the classroom. The worksheets were found to be useful in preventing students from becoming merely passive observers. However, the worksheets must be coordinated carefully with the computer display. The worksheets may be employed to record a limited quantity of the results and calculations, but they should not be used merely for students to copy large quantities of numbers displayed by the computer. Alternatively, worksheets may be used to allow students to anticipate the forthcoming computer displays. The idea of competing (in a sense) against the computer encourages student participation.

Third, if possible, a version of any CAL module employed in the classroom should be made available for individual student use in the computer laboratory. This allows students to review the material at their own pace. Finally, the successful use of CAL materials in the classroom is dependent on the availability of suitably located monitors to ensure that all students are able to see the computer display clearly.

Example 2: TRAFLOW

The TRAFLOW packet is designed to aid students in reviewing and studying basic concepts of traffic stream flow, including density, speed, and flow, and the relations among these variables. For example,

one module in this packet allows the user to fit a linear speed-density model to a set of data and to explore the corresponding speed-flow and flow-density relations. TRAFLOW is a drill, practice, and tutorial packet designed for computer laboratory use by individual students.

At present the TRAFLOW packet comprises six modules. Briefly, the function of each of these modules is as follows.

1. INTRO--Provides information that allows the user to determine whether to use this packet, which section is an appropriate starting point, and how to use the packet;
2. PRETEST--Enables the user to assess and improve his or her understanding of the fundamental concepts that are prerequisites for the other sections of the packet;
3. PLATOON--Presents data concerning the movement of a platoon of vehicles over a highway segment; the data enable the user to compute traffic stream flow characteristics in response to questions posed by the module; the data are generated randomly and the user may to choose to repeat another problem of the same type as many times as desired;
4. LINEAR--Presents a speed-density plot of field-collected data (13); the user is able to fit a linear speed-density model to the data and is then guided through an examination of the corresponding speed-flow and flow-density relations;
5. NONLIN--Introduces the user to the idea of nonlinear speed-density models and the implications of this form of the speed-density model for the corresponding speed-flow and flow-density relations; and
6. SUMMARY--Provides a summary of the material in the packet and allows the user to obtain a printed copy of a list of references that deal with the basic concepts of traffic stream flow.

Features

A number of features are incorporated in the TRAFLOW packet. A simple set of commands allows the user to control the lesson. The user may choose to advance to the next frame, start the module again, end the module, skip to another module, or leave a message for the instructor. The latter option can be particularly helpful in providing feedback for the instructor and in allowing the user to express any frustrations that may have been generated by the CAL package.

At the end of each series of questions the user is provided with an evaluation of his or her performance. The ability to provide rapid feedback is an important characteristic of CAL technology, yet a number of drill, practice, and tutorial packages do not provide any assessment of the user's performance. The TRAFLOW packet provides for individualized learning in that the user is given the option of receiving additional explanations when desired. The user is also able to select the order in which the different topics are reviewed or studied, after being supplied with the information needed to make such decisions. Grubb (14) makes a strong argument for granting the user more control in order to allow for wide differences in individual backgrounds.

Assessment

All of the students responding to the questionnaire thought that CAL modules generally have a use in the drill, practice, and tutorial modes, and they enjoyed using the TRAFLOW packet. All the respondents considered TRAFLOW to be an effective aid in re-

viewing the basic concepts of traffic stream flow, although not as effective as individual interaction with the instructor. All of the respondents availed themselves of the opportunity to obtain a hard copy of the references, but few left messages for the instructor.

A number of the students thought that they could have been better prepared before using the TRAFLOW packet; in particular, by suitable review of their class notes. A drill, practice, and tutorial CAL packet should not require that students be thoroughly familiar with the subject matter before using the packet. Although the TRAFLOW packet assumes that the user has been introduced to the basic concepts, it is designed to assist students in reviewing and understanding these concepts. The reason why a number of the students thought that they could have been better prepared is not clear.

The majority of the respondents thought that the answers provided are not detailed enough for effective learning. In particular, two important considerations emerged. First, an explanation of the recommended solution should be provided rather than just a step-by-step account of the solution procedure. Second, even if a student answers a question correctly, he or she should be given the option of requesting an explanation, particularly if a multiple-choice format is employed.

Example 3: UTP

The objective of the UTP packet is to aid students in carrying out the repetitive and time-consuming calculations necessary for an urban transportation planning case study undertaken in the introductory transportation engineering course at Duke. The case study, which is based on one developed by Morlok (15), uses a very small, hypothetical study area and is undertaken by groups of three students each. A large number of repetitive computations are needed to examine each alternative transportation system for the study area. The UTP packet is designed for use in the computer laboratory by individual students or by small groups. The packet's design prevents its use as a black box. That is, the packet does not eliminate the students' need for understanding the basic principles and techniques.

The UTP packet comprises three modules, INTRODUCTION, GRAVITY, and BALANCE, and at least three more are planned. Each module is designed to constitute a single session at the computer. Each of the modules, other than the introductory one, is designed to deal with one phase of the analysis of an alternative transportation system.

Features

Problem-solving is one of the variety of modes in which the computer can be used in the educational context. However, some educators believe that the use of computers as computational aids can be detrimental because it reduces the students' need for understanding basic principles and techniques. For example, de Silva (16) has published an article entitled, *The Computer: Obstacle to a Meaningful Engineering Education*.

The UTP packet is based on the belief that suitably designed software can be used successfully as a problem-solving tool in the educational environment. In developing the UTP packet we hypothesized that the reduced time and effort needed for calculations would encourage students to explore a greater variety of alternative transportation plans for the study area. Furthermore, we hypothesized that the UTP packet would allow the students to gain improved understanding of the basic concepts, rela-

tions, and techniques, as long as it could not be used as a black box.

The characteristic that best distinguishes the UTP packet from software used by professional transportation planners is that the UTP packet is structured on the assumption that the user is inexperienced and is relatively unfamiliar with the principles and techniques. The user is therefore required to develop and demonstrate a thorough understanding of each particular computational technique before being able to employ a given module as a computational aid. The package is also designed for use with only a limited range of problem types, in contrast with the flexibility necessary in industrial software.

Each module includes a number of questions to probe the user's understanding of the planning process and model system. In particular, the input and output variables for each model are reviewed. An incorrect response to a question automatically generates the correct answer as well as additional information concerning the modeling technique being employed. After completing the question segment of a given module, the user is asked to input the data required for the calculations and to provide the first series of results. These results are examined for consistency relative to the input data provided by the user. If the calculated results are incorrect, the user is so informed and is given another opportunity to perform the calculations manually. Correct results enable the user to proceed with the use of the CAL package as a computational aid in the current and subsequent sessions. The module is therefore able to provide many of the insights usually obtainable only through manual computations and also eliminates tedious and repetitive calculations.

Assessment

Student reaction to the UTP packet was generally positive. More than 70 percent of the users found the modules useful, mainly for simplifying computations. Only 18 percent of the users found the modules to be of no help in improving their understanding of the transportation planning methods and in formulating questions to be discussed with the instructor. Furthermore, only 12 percent thought they would have learned as much as they did from the case study project without the UTP packet; about 40 percent of the respondents appear to have used some of the modules for personal review of the material. Only one respondent thought that the UTP packet rendered the instructor unnecessary, and about a third of the respondents thought that the help provided should have been more detailed.

The success of the UTP packet is confirmed by three observations made by the instructor and teaching assistant. First, the UTP packet encouraged considerable interaction among the group members--probably because the computer engages the students in an us versus the machine situation. Second, some groups undertook analyses that were not attempted the previous two times the case study was assigned, without the availability of the UTP packet. This was probably due to the reduced amount of time spent on the calculations as well as the greater insights gained. Third, the course evaluations in the past have revealed that the students generally find the case study project interesting and didactic, but extremely time-consuming. However, the previous complaints about the large amount of time spent doing repetitive calculations were absent when the UTP packet was available. A more detailed assessment of this packet is provided elsewhere (17).

DISCUSSION OF RESULTS

Relatively little use has been made of CAL in transportation engineering education, despite the extensive renewed interest in this technology during the past five years. Because of the potential benefits of careful and appropriate uses of CAL, transportation educators should begin exploring possible applications.

Three examples of CAL applied to transportation engineering topics are described and assessed in this paper. These examples demonstrate some potential uses of CAL in different contexts in transportation education. The examples indicate potential benefits of CAL in transportation education and they highlight some of the considerations that are important in developing CAL materials in different contexts. This paper shows how the computer can be used effectively in the classroom to aid the instructor in demonstrating an iterative solution technique. The paper also describes how the computer can be used appropriately as a problem-solving tool in the educational environment.

An area of transportation engineering that should be explored for potential use of CAL is the collection and analysis of field data. In some cases the real-world process could be simulated effectively on the computer in such a way as to allow the student to gain a good understanding of the data collection and analysis procedures. Such applications could eliminate the need for field equipment and reduce the time needed to acquire the necessary skills. Computer simulations of chemistry and physics experiments are already in use. A second area of transportation engineering in which CAL might be employed is geometric design. Computer graphics could be used to demonstrate the interaction of the various design elements--both in the classroom and in the computer laboratory.

The potential usefulness of CAL in transportation engineering education has been demonstrated in this paper. An indirect benefit of CAL is that students become more comfortable with the use of computers and they see the range of tasks that can be accomplished with a computer. The example applications illustrate some of the considerations that are important to the successful development and use of CAL. Transportation educators should begin to explore this powerful educational technology. In addition to considering the guidelines presented and discussed in this paper, the interested transportation educator should examine the ideas presented by Bork (18), Eisele (19), Nievergelt (20), and Spitler and Corgan (21).

Finally, CAL is not the solution to all educational problems, and transportation educators should evaluate carefully the application of this technology in their courses.

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