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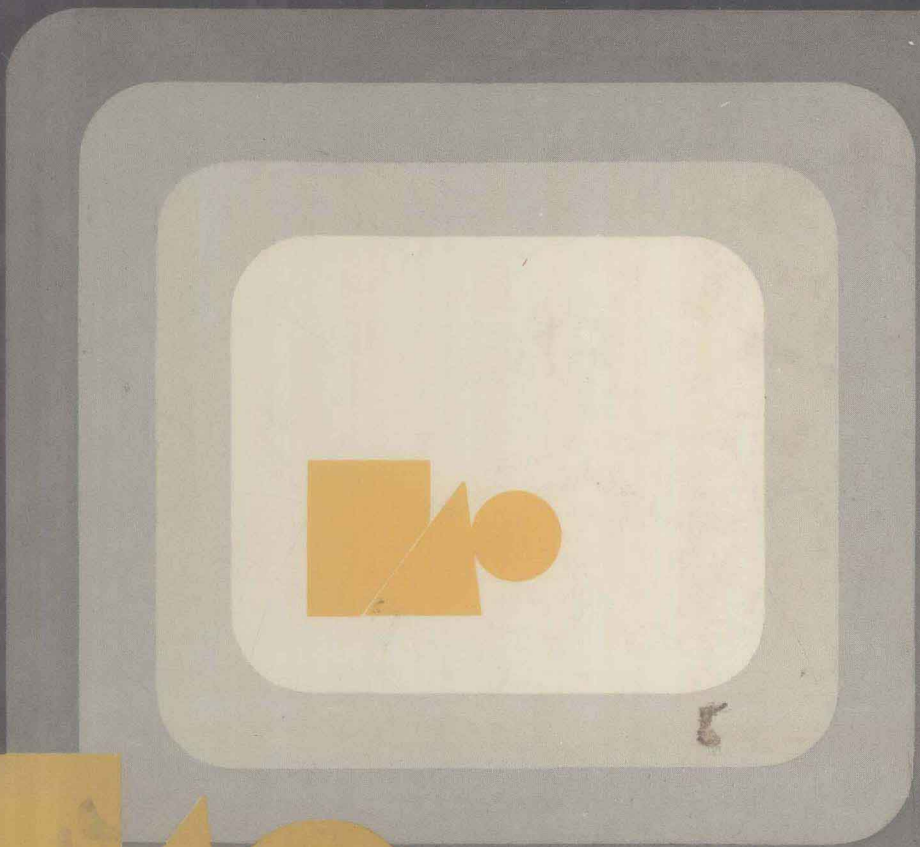
COMPUTERS AND THEIR APPLICATIONS

Interactive Computer Graphics in Science Teaching

edited by J. McKENZIE L. ELTON R. LEWIS



INTERACTIVE COMPUTER GRAPHICS IN SCIENCE TEACHING

Interactive Computer Graphics in Science Teaching

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ELLIS HORWOOD LIMITED
Publishers **Chichester**

Halstead Press: a division of
JOHN WILEY & SONS
New York · Chichester · Brisbane · Toronto

The publisher's colophon is reproduced from James Gillison's drawing of the ancient Market Cross, Chichester

First published in 1978 by

ELLIS HORWOOD LIMITED

Market Cross House, 1 Cooper Street, Chichester, Sussex, England

Distributors:

Australia, New Zealand, South-east Asia:
Jacaranda-Wiley Ltd., Jacaranda Press,
JOHN WILEY & SONS INC.,
G.P.O. Box 859, Brisbane, Queensland 40001, Australia.

Canada:
JOHN WILEY & SONS CANADA LIMITED
22 Worcester Road, Rexdale, Ontario, Canada.

Europe, Africa:
JOHN WILEY & SONS LIMITED
Baffins Lane, Chichester, Sussex, England.

North and South America and the rest of the world:
HALSTED PRESS, a division of
JOHN WILEY & SONS
605 Third Avenue, New York, N.Y. 10016, U.S.A.

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British Library Cataloguing in Publication Data

Interactive computer graphics in science teaching. –
(Ellis Horwood series in computer science).
1. Science – Study and teaching (Higher) 2. Science –
Computer – assisted instruction 3. Computer terminals –
Interactive terminals 4. Information display systems
I. McKenzie, John, b. 1933 II. Elton, Lewis Richard
Benjamin III. Lewis, Robert IV. Series
507'.8 Q181 78-40598

ISBN 0-85312-109-5 (Ellis Horwood Ltd., Publishers)

ISBN 0-470-26419-5 (Halsted Press)

Typeset in Press Roman by Ellis Horwood Ltd.,
Printed in Great Britain by Cox & Wyman Ltd., of Fakenham

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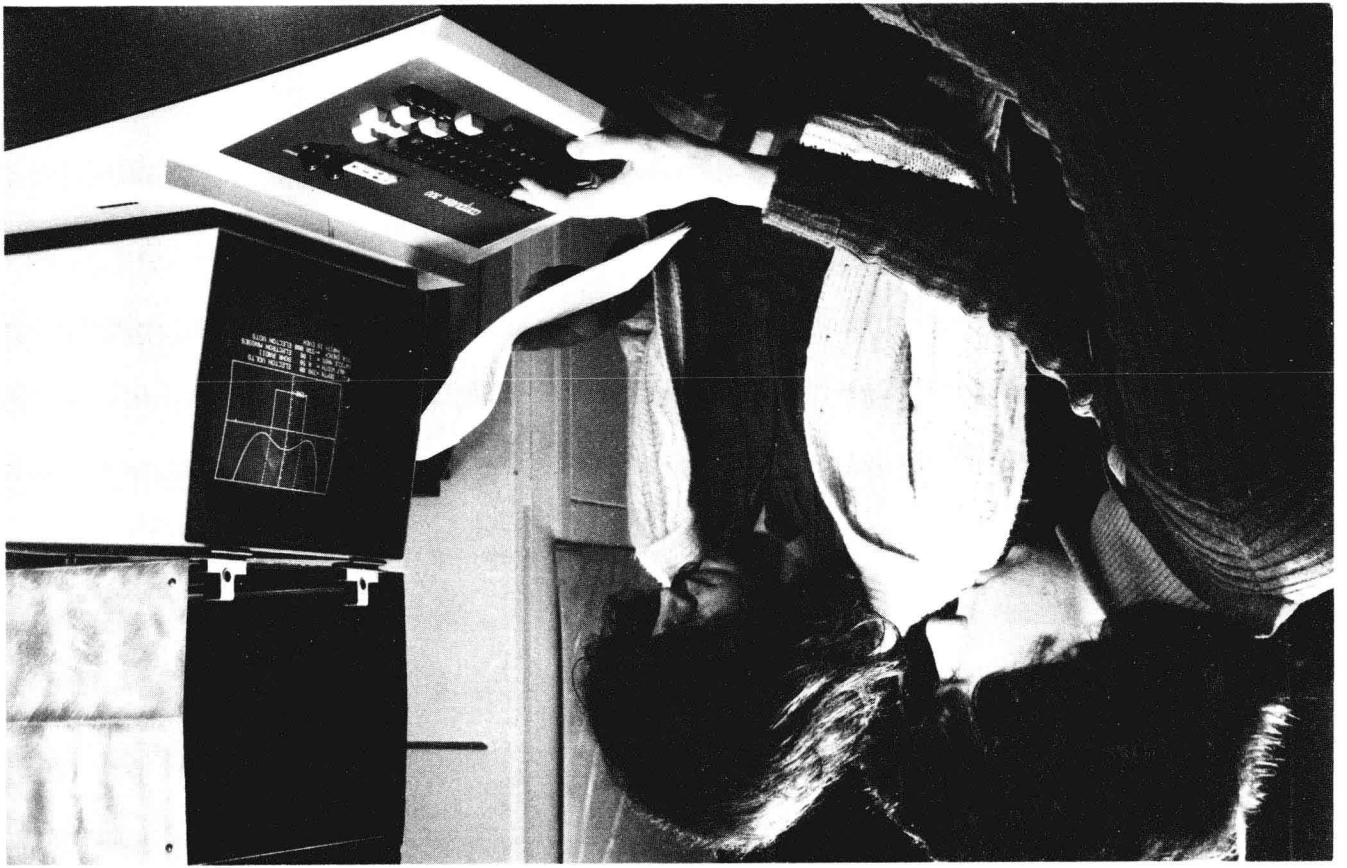
Foreword

This book is an important product of an unusual collaboration of interests. An expanding group of physicists, chemists and biologists from two (now three) University of London colleges and the University of Surrey have over the past 4 years been developing advanced applications of the computer to undergraduate science teaching. The central focus of the work has been the exploration of the educational uses of the graphical power of the modern computer.

The work of the group, as discussed in this book, is important and distinctive for at least two reasons. First of all, the collaborating teachers have amply demonstrated that the concept of CAL (computer assisted learning) is far richer and broader than the narrow stereotype of computerised programmed learning. Indeed, the programmed learning era of CAL, in the USA in the 1960s, may prove to be a historical aberration. Secondly, the group has shown that the NIH (not invented here) syndrome is far from being an inevitable feature of higher education. Given care and commitment, it is perfectly possible for teachers to collaborate between institutions and across disciplinary boundaries. Such collaboration can lead to the production of imaginative teaching materials which will be used on a regular basis with students in different courses.

The book is important because it records four years' experience of CAL development, so that new groups of CAL practitioners will not need to reinvent all the same 'wheels' at great expense. New groups of CAL practitioners could have no better guides to this complex and fascinating teaching environment than the authors of this book.

RICHARD HOOPER
Director
National Development Programme
in Computer Assisted Learning.
London, Summer, 1977.



Chapter 1

Introduction

Interactive computer graphics is a relatively new tool in the workshop of educational technology, and is an increasingly important aspect of **computer assisted learning** (CAL). The enormous potential of computer graphics for teaching and learning has been obvious for almost as long as there have been computers, but it is only recently that the costs of the necessary equipment have begun to fall to a level at which the technique can be applied in conventional education, rather than being restricted to specialised uses in research or military training.

In undergraduate teaching, the use of interactive graphics allows great scope for presenting the qualitative aspects of a system, which can so easily be obscured by too much emphasis on the underlying mathematics. As an example, consideration of the table of data in Figure 1.1 will probably reveal little, if any, of its qualitative import, and yet the same data presented graphically in Figure 1.2 carries considerable qualitative information, even when the subject matter is unfamiliar. The use of *graphics* alone is not new, since the power of a picture to convey a great deal of information in assimilable form has been understood for centuries. It is the combination with *interaction* that becomes so powerful a tool for learning, because the student is forced to become an active participant who must remain alert and decide on the next action, rather than say passively listen to a lecture or watch a film.

1.1 THE SCOPE OF THIS BOOK

The book is an attempt to provide a useful guide for anyone who would like to know more about the technique, and in particular those who are considering whether to use interactive graphics to augment their own teaching. It is based on experience gained during four years of CAL (mostly graphics) and is recorded by the practitioners themselves, while they are still bound together in a working collaboration. The contributors include academic teachers who have been especially innovative with CAL, and specialists in computing and education who have worked full-time in the collaboration to develop materials.

$R = 0.2$

$\phi/2\pi$	I/I_{max}	$\phi/2\pi$	I/I_{max}	$\phi/2\pi$	I/I_{max}
0.00	1.000	.35	.502	.70	.550
.05	.970	.40	.469	.75	.615
.10	.893	.45	.451	.80	.698
.15	.795	.50	.444	.85	.795
.20	.698	.55	.451	.90	.893
.25	.615	.60	.469	.95	.970
.30	.550	.65	.502	1.00	1.000

$R = 0.5$

$\phi/2\pi$	I/I_{max}	$\phi/2\pi$	I/I_{max}	$\phi/2\pi$	I/I_{max}
0.00	1.000	.35	.136	.70	.160
.05	.836	.40	.121	.75	.200
.10	.567	.45	.114	.80	.266
.15	.378	.50	.111	.85	.378
.20	.266	.55	.114	.90	.567
.25	.200	.60	.121	.95	.836
.30	.160	.65	.136	1.00	1.000

$R = 0.8$

$\phi/2\pi$	I/I_{max}	$\phi/2\pi$	I/I_{max}	$\phi/2\pi$	I/I_{max}
0.00	1.000	.35	.016	.70	.019
.05	.338	.40	.014	.75	.024
.10	.116	.45	.013	.80	.035
.15	.057	.50	.012	.85	.057
.20	.035	.55	.013	.90	.116
.25	.024	.60	.014	.95	.338
.30	.019	.65	.016	1.00	1.000

Figure 1.1 Tabulated values of the function $\frac{I}{I_{max}} = \left[1 + \frac{4R}{(1-R)^2}\sin^2\frac{\phi}{2}\right]^{-1}$

It is hoped that the book will provide not only a coherent development of the subject if read in page order, but also a guide that can be dipped into for material of special interest. For example, the science teacher may wish to begin by turning straight to the chapter that discusses his own subject (whether physics, chemistry or biology) and discover from the many examples given there both the kinds of topic that can benefit from CAL and ways in which the computer can be

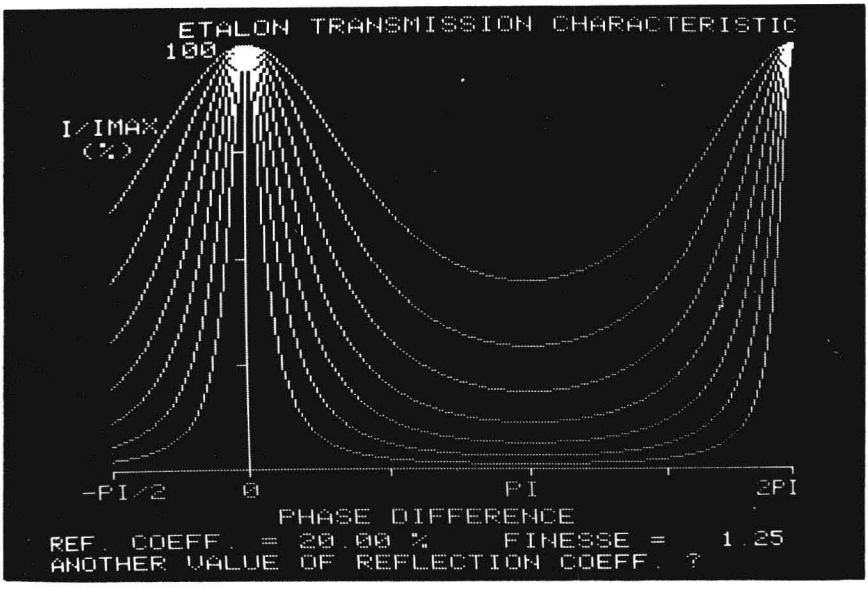


Figure 1.2 Graphical plot of the function tabulated in Fig. 1.1, for six values of the parameter R.

used. The teacher may also wish to read the personal views of fellow teachers given in Chapters 10 and 11, before reading Chapter 2 to learn about the educational material that must be developed in addition to a computer program. Chapters 3 to 5 are concerned with technical matters of terminals, computers, and software, but they have been written primarily for the benefit of teachers who are not specialists in these matters, and care has been taken to provide an explanation of technical terms as they arise. This is backed up by the technical Glossary in Appendix A. The educational technologist will probably prefer to begin with the accounts of educational design, evaluation and transfer given in Chapters 2, 9 and 12, whereas the computer specialist who foresees a need to provide a service for CAL will find it helpful to read through Chapters 4 and 5, and then consider the discussion of possible costs, including the less obvious ones, in Chapter 13.

1.2 THE MEANING OF CAL

The modern computer began as a highly specialised tool for scientific research. It has steadily grown in power to become so versatile that it is not only indispensable for research, but also has a multitude of applications to everyday life. One result of this versatility is that there are many types of CAL, with no single meaning that is universally recognised.

For the present purpose, CAL is taken to mean the use of the computer to provide learning opportunities that can be provided by no other educational medium. The object is thus to make use of properties of the computer that are peculiar to it, such as its ability to perform lengthy calculations rapidly and accurately. This permits the use of real-life examples rather than artificial ones that happen to have straightforward solutions. More significant still is the computer's ability to hold the program of a model which can be explored by changing parameters over a wide range. The manipulation of the model by a student can be closely guided, yet it can be extended to a more open-ended exploration in which the computed results from one set of parameters are used by the student to influence his decision about how, and how much, to change the next set. Such models can be used to simulate experiments that would not in practice be performed in a teaching laboratory, either because they are too lengthy, complicated or dangerous, or because they are inherently impossible (as when 'looking' inside atoms).

This mode of use, mainly for simulation, has been called 'computer as laboratory', and the analogy is close. A set of guiding notes is necessary to help the student get the most out of a program, just as it is for an experiment. The combination of computer program with associated educational material for the student (and possibly the teacher also) is known as a CAL **package**.

Having outlined what is meant by CAL, at least as far as the present work is concerned, it is worth mentioning some uses of the computer within education that are not included here, to avoid any misunderstanding. One large area is the application of computers to assist with timetabling, scheduling, or marking and grading assignments. In this mode the educational materials themselves are conventional, and the role of the computer is a managerial one. It is therefore generally known as **computer managed learning**, or CML.

Probably the most widespread alternative to CAL is CAI, **computer aided instruction**. When computers were first applied to teaching and learning in the 1960's, it was hoped that they would provide more effective education at a lower cost than formerly, and that they would individualise instruction. The first hope was linked, particularly in the United States, with the need to teach enormous first-year classes whose very size might allow economies of scale which would justify the costs of installing a large computer. The second hope was that the computer would be a tutorial teaching machine, able to respond with individualised help to a student in difficulty. Neither hope has been fulfilled, except possibly for drill-and-practice of relatively low-level skills. The costs of a computer installation are never matched by savings elsewhere, and the computer, for all its power, cannot begin to compete with a human tutor for range and subtlety of conversational response. CAI is essentially an attempt to mechanise instruction that is conventional in other respects, primarily in order to cope with a large student/teacher ratio.

The approach of CAI stands in contrast to that of CAL, where a qualitatively

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