AUTHOR: Frances Aldrich, Yvonne Rogers and Mike Scaife
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ABSTRACT

Many commercial CD-ROMs are now being marketed as suitable for home and school use, increasingly promoted as covering the National Curriculum. However, such promises are failing to be realised because many CD-ROMS are poorly constructed, consisting simply of a mishmash of images, sounds and video that offer little more than light entertainment. The aim of this paper is to provide guidance on assessing the added value of educational CD-ROMs compared with traditional materials by explicating more the notion of interactivity as it pertains to learning.

INTRODUCTION

Many commercial CD-ROMs are now being marketed as suitable for home and school use, increasingly promoted as covering the National Curriculum. There has been much marketing hype and glowing reviews in the popular press about their benefits for education. For example, a typical claim by Holzberg (1994, 57) is: "thanks to the flashy sound and brilliant graphics that make multimedia CD-ROMs so appealing it's easier than ever before to turn kids onto learning". However, such promises are failing to be realised and teachers and parents alike are becoming more wary of spending large amounts of money on "whistles and bells", having been disappointed with the quality and educational value of CD-ROMs already purchased. A central problem is that many CD-ROMS are poorly constructed, consisting simply of a mishmash of images, sounds and video that offer little more than light entertainment.

Such a state of affairs does not mean, however, that we should simply abandon CD-ROMs as an educational resource. Far from it, since the technology itself provides much scope and opportunity for developing innovative and computationally powerful interactive educational material (Rogers and Scaife, 1997). The key is knowing how to put the interactivity potentially provided by the technology to good use. Essentially this involves designing effective activities that are engaging but also enable the learner to understand concepts and to reflect on and integrate different kinds of knowledge. Some CD-ROMs have been more successful than others in achieving these levels of interactivity. This leads us to ask the question, how can teachers and parents be helped in sorting the wheat from the chaff when confronted with an ever increasing catalogue of CD-ROMs? As one teacher put it to us, "You get the title and a brief resume of what's on the disk but you get no idea of what it's like to use—you're shooting in the dark!". Importantly, even when a copy of the disk has been obtained, there is surprisingly little guidance on how to appraise the learning value of the interactivity it offers. Most instruments available for reviewing and evaluating educational software are concerned primarily with the accuracy and scope of the content, the appropriate age range and group size for its use, the robustness and usability of the software, the availability of paper-based support materials, and basic technical requirements (eg Squires and McDougall, 1994). Whether the interactivity offered by the software offers advantages over traditional materials remains a much neglected issue.

The aim of this paper is to provide guidance on assessing the "added value" of educational CD-ROMs compared with traditional materials by making more explicit the

notion of interactivity as it pertains to learning. Interactivity is a key aspect of multimedia software, distinguishing it from traditional "passive" media, ie, books, video and radio. Specifically, learners can interact with multimedia in more and varied ways than they can with traditional media. A problem, though, is knowing how to identify the interactivities that support effective learning compared with those that are largely superficial. Currently, teachers and parents have little to go by. Below we describe a study where we asked teachers to assess two representative science CD-ROMs with the goal of making explicit key aspects of interactivity from their perspective. Using the findings in combination with our own conceptual analysis of interactivity, we have developed a method for helping teachers and others evaluate the educational value of interactivity, exemplified by CD-ROM technology. We start by outlining advice currently available to teachers for selecting CD-ROMs and then present an analysis of interactivity in relation to learning.

GUIDANCE AVAILABLE TO TEACHERS FOR SELECTING CD-ROMS

Although classroom-oriented reviews can be found in educational software catalogues they are invariably positive because the aim is to market the disks (eg, The Complete Primary Software Catalogue, 1996). More balanced school-oriented reviews sometimes appear in teaching magazines (eg, the Primary Science Review), but the most comprehensive source is the CD-ROM Titles Review produced by the National Council for Educational Technology (1995). This contains reviews of about 400 disks by people with a wide range of primary classroom experience. The review team were asked to consider a range of aspects including (p. 5):
* The adequacy of both content and coverage
* The appropriateness to the National Curriculum in England
* The appropriateness of Reading Age for Key Stage (KS) 1 and KS 2 pupils
* The quality of interface design, presentation, degree of interactivity, and range of facilities
* The quality of support materials (where submitted)
* The overall quality of the title

The emphasis of the guide, however, is very much on highlighting the volume of information on the CD-ROMs rather than their interactivity value with respect to learning. Reviews are restricted to about 200 words. Within these often only three or four sentences are to do with "the quality of interface design, presentation, degree of interactivity and range of facilities". Even within these, the potential value of interactivity is only indirectly referred to. Instead, there is more emphasis on search features and the development of information-handling skills. Almost as an afterthought teachers are advised to look out for CD-ROMs which "allow children to add their own voices and text, or grab pictures, sounds and text to put into their own work" (p. 489).

As an alternative, teachers themselves can get more involved in reviewing CD-ROMs in relation to their ideas of what kinds of interactivity are important in a classroom context. One example of this collective self-help approach can be found in the "CD-ROM Advisor", a magazine aimed at the home market which requests readers to send in reviews commenting briefly on likes and dislikes about a disk, and asking them to rate the following factors:
* "fun"—how compelling the disk is
* "quality"—the accuracy of the information and the effort put in by the publishers
* "multimedia impact"—its use of movies, sound and animation
* "overall satisfaction"—would the user recommend the disk?

Here again the focus is on potentially superficial aspects of interactivity that bear little or no relation to learning benefits. In both approaches, therefore, teachers are

given little guidance about how the forms of interactivity can map onto their teaching goals and can help them improve children's learning of a subject.

So how can we help teachers more effectively assess and become aware of the value of interactivity when selecting CD-ROMs? To begin to help we need to have a better conceptual framework for analysing interactivity.

WHAT IS "INTERACTIVITY?"

The term "interactivity" has become ubiquitous. All around us we hear about the alleged benefits of interactive TV, interactive multimedia, interactive video, etc. Paul Sargeant, writing in the Guardian Higher Education Supplement recently, described "the four syllables in-ter-act-ive" as "like the jangle of loose change in the marketing man's highly sensitive ears" (Sargeant, 1997). Typically, the term interactivity is directed at the level of the interface—the user takes some action (eg, clicking a button or dragging an object on screen) and the computer responds to that action (eg, by playing a sound, running an animation or displaying new text). Many CD-ROM reviews reflect a pre-occupation with this level of "reactive" interactivity, for example "there are lots of opportunities to press things on-screen and see interesting bits of animation" (CD-ROM Titles Review, 1995, 363). However, this level of description overlooks any notion of a goal underlying the exchanges between the computer and the user, and can include activities as aimless as the user hitting keys at random—what Plowman (1996) refers to as "gratuitous interactivity".

A further aspect of the hype about interactivity is the simplistic assumption that it is a panacea for education. When coupled with multimedia technology it is often assumed that the two will allow "every person to discover knowledge in the pattern that fits their paradigm for learning" (Taylor, 1990, 27). But as pointed out by Reeves (1993, 80) the two cannot automatically improve learning "any more than a library in a school can" and "multimedia without the interpretive acts of learners is only a collection of textual, graphical and audio elements".

The critical question is: what is it about interacting with multimedia that has the potential of engendering more effective learning than with other traditional media? To answer this, we need to have a better understanding of the concept of interactivity in relation to the kinds of learning that can be mediated by interacting with different media. This requires us to have a more theoretically-driven level of explanation that focuses explicitly on the kind of cognitive activities (ie, learning, problem-solving and memory tasks) that take place through the physical activities afforded by the interface.

Within the educational technology literature there have been several classifications of interaction types in relation to learning. A common one describes learning as taking place on a continuum, from reactive to proactive (eg, Lucas, 1992; Thompson and Jorgensen, 1989; Rhodes and Abzell, 1985). Here the focus is on mapping models of learning (eg, behaviourist, constructivist) to types of learning environments. For example, a reactive model of interactivity is one which has been designed to support learning through drill and practice/reaction and response mode. Conversely, proactive learning is thought to take place through the user being involved actively in the construction of the knowledge. This includes situations where the computer is used as an object to think with, such as providing tools for children to discover ways of measuring time. Other classifications of interactivity and learning have focused more on helping designers support different kinds of learning, through using different kinds of navigation and user control mechanisms. For example, Sims (1997) discusses a range of interactivities, like "update interactivity" and "reflective interactivity", where he suggests that applications should be designed to present problems to which the learner is required to respond and which are available to other students to look at and compare their answers with.

Whilst these taxonomies of interactivity go some way towards clarifying the notion of interactivity in relation to learning, they overlook critical aspects of user engagement which are an integral part of learning (Draper, 1996; Laurillard, 1995; Giardina, 1992). These are the "internal" processes that go on within learners when interacting with different media and other people (ie, teachers, peers). Whether they are observing an animation, browsing a book, answering a quiz, having a discussion or constructing a model, there are different kinds of cognitive activities going on. We need to understand interactivity, therefore, not simply in terms of "physical activities at the interface" or in global terms of supporting models of learning but in terms of the cognitive interplay between internal and external representations that arise in the different settings (see Scaife and Rogers, 1996). By this we mean the process by which people integrate representations of the same and different information. This requires analysing how they learn to read and comprehend the significance of the content of different media and how this is assimilated with their current understanding of a domain, at different stages of the cognitive task. For example, reading and abstracting knowledge from a graphical representation (eg, a diagram) requires making connections between different elements of the display in a temporal sequence, using both internal and external representations in concert.

In turn, we need to operationalise our theoretical accounts of interactivity in terms of applied guidance which is useful to different audiences (eg, teachers, parents and designers) for the purpose of designing and evaluating interactivity with their differing goals in mind. We have already discussed elsewhere how to do this as practical guidance for designers (see Scaife and Rogers, 1996; Rogers and Scaife, 1997). There we presented a framework that identified a range of cognitive properties that can be attributed to external representations which make them more or less easy to interact with (see Table 1). We have also described the kinds of interactivity that would be useful for helping university students learn about interface design through using CD-ROMs (see Rogers and Aldrich, 1996). These include a range of hands-on activities where the students are provided with opportunities to put theoretical ideas, models and design concepts into practice. In this paper our focus is specifically on developing a framework, consisting of a set of questions and dimensions, that teachers can usefully employ when thinking about the added value of interactivity for use in their teaching.

THE STUDY: OPERATIONALISING THE CONCEPT OF INTERACTIVITY IN TERMS OF TEACHING GOALS

As mentioned earlier, currently available methods for reviewing educational software have not been useful for guiding teachers to think about the benefits accruing from interactivity. A main objective, therefore, was to develop an "assessment" framework geared to teachers, to enable them to evaluate more effectively the educational merit of CD-ROMs with respect to their interactivity (and thus learning) potential. By evaluation in this context we mean: to carry out a study which systematically assesses the pros and cons of a software package (CD-ROM), against a set of pedagogical criteria.

A study was carried out initially to identify those aspects of interactivity in CD-ROMs which teachers thought were important for primary school teaching. A panel was set up consisting of a representative set of primary school teachers. They were asked to assess two science-based CD-ROMs, using a questionnaire, and were subsequently brought together in a focus group to discuss the findings. Based on these results, together with our theoretical analysis of cognitive interactivity, a framework was developed which was intended to be generalisable to educational domains other than science, and applicable to learners of all ages.

PARTICIPANTS

Eight primary school teachers took part in the study. All were interested in CD-ROMs, although not necessarily skilled in their use. All had experience of science teaching.

THE CD-ROMS

Two CD-ROMs were deliberately chosen to provide a contrast in format and interactivity. Both are marketed as educational disks on the topic of ecology. Food Chains and Webs (1995) explicitly aims to teach a defined set of ecological concepts (eg, notions of producer versus consumer, pyramid of numbers, etc.), using a short audio-visual presentation followed by interactive question and answer sections. Learners are encouraged to progress through the sections in numbered order rather as though it were a book. In the Desert (1995) also aims to present ecological concepts but in a more indirect way since concepts (such as food chains) are implied rather than identified explicitly. It does so by explaining the elements of the desert ecosystem, and giving details of how example plants and animals have adapted to the habitat. Learners find out about these by clicking on pictures within a desert panorama, and can also "enter" a visitor centre to consult a library of on-screen books. There is no prescribed order of progression through the contents of this disk. An accompanying booklet is provided for teachers, where it states that the "ideal learning environment should not satisfy children's curiosity, but instead, present them with new things to be curious about". Both disks make ambitious claims on the packaging (eg, "intuitive interface", "experience the excitement").

THE METHOD

Participants were lent a computer and the two CD-ROMs at home for a week, to carry out the assessment in their own time. They were asked to explore the CD-ROMs with regard to their potential for classroom use, looking first at Food Chains and Webs and then In the Desert. It was suggested that while they explored the CD-ROMs they might find it helpful to think about the questions posed by the questionnaire, which they should complete immediately after finishing with each disk. They were advised to allow four hours for the entire task.

The questionnaire was designed to be open-ended, with the aim of eliciting aspects of the CD-ROMs that teachers considered important or problematic. Through this we hoped to obtain information from the teachers about their current thinking about interactivity. The principal questions were:

* What aspects do you most like about this disk?
* What aspects do you least like about this disk?
* What was motivating?
* Do you think this disk offers any advantage over the mix of traditional media you might otherwise use? Why?
* Were your expectations met?

FINDINGS

From the results of the questionnaires, it was clear that overall the teachers were disappointed with Food Chains and Webs ("very limited and basically boring", "hard fact cramming", "much duller than I expected") and preferred In the Desert ("inventive and fun, met all my expectations", "in a different league to Food Chains and Webs"). However, our concern here is not which disk they preferred but why, and so from these data we analysed which aspects of interactivity teachers consider important for learning.

As expected the teachers' responses reflected a wide variety of considerations about the CD-ROMs including level, scope and clarity of presentation; accessibility for

children with special needs; feasibility of class use; teacher time savings; National Curriculum requirements; and value for money. However, the strong preference for In the Desert was clearly attributable to the greater level of interactivity it offered, through which they experienced a much higher level of engagement. This is reflected in the comments below, which are classified according to two different aspects of learning ("Motivation and Engagement" and "Learning Style") and also in comparison with other media:

MOTIVATION AND ENGAGEMENT

FOOD CHAINS AND WEBS

   * its rigid structure ... would not necessarily hold a child's interest for very long

IN THE DESERT

   * the format stimulated curiosity and a sense of adventure
   * the way of finding out information is very creative and interesting
   * interesting, adventurous, challenging and diverse
   * it's the diversity that makes it so good. A real learning tool. You want to seek out all the facets.

LEARNING STYLE

FOOD CHAINS AND WEBS

   * very linear and logical progression which resulted in a course of work which was clear and unambiguous

IN THE DESERT

   * learners can select their own focus
   * steer their way through the disk at their own pace with their own direction

COMPARISON WITH OTHER MEDIA

FOOD CHAINS AND WEBS

   * the disk was really only one step ahead of a chalk and talk comprehension exercise, ie, the children listen to the "lesson", do the "exercise" and then the "test"
   * there was no real interaction, the children were not required to think, just remember facts

IN THE DESERT

   * allows you to explore and browse in a way traditional media do not—a more "hands on" experience
   * short video sequences bring the books to life

In sum the study identified a variety of factors about the CD-ROMs which the teachers considered important with respect to their teaching goals. In particular, the teachers paid a great deal of attention to how children might learn from the CD-ROM, as well as what they would learn. During the focus group session the teachers' discussion of interactivity centred on learning activities which the CD-ROMs supported, such as "answering questions", "making notes", "taking photos" and "exploring the landscape". For them it was important that a CD-ROM provide a range of these kinds of interactivities. When asked what other kinds of interactivity a CD-ROM might be useful for, suggestions included:
   * virtual field trips to places not accessible to the children
   * experimentation which is not possible in real-life (eg, with the solar system)
   * simulation to explore "what-if" scenarios which could not be tried in real-life (eg, polluting a pond)

Here the teachers are identifying the need for purposeful activities that enable the learners to solve problems, reflect, imagine and create. In particular, a general request

was for CD-ROMs to provide children with opportunities to carry out activities that they could not do otherwise with traditional materials. Thus teachers, themselves, were very aware of the kinds of interactivities that support effective learning. What we aimed to do next was to utilise these findings in combination with our theoretical analysis of interactivity to devise an assessment framework for teachers to use to determine more accurately whether a CD-ROM supports the various kinds of learning interactivities they are interested in.

A FRAMEWORK FOR HELPING TEACHERS IDENTIFY APPROPRIATE INTERACTIVITIES

To identify the educational value of a CD-ROM, it is important to clarify the relationship between the different kinds of interactivities provided and how they can support learning of the particular topic. To begin with we list the activities which the CD-ROM offers the learner. Table 2 shows the activities of which the teachers in our study made specific mention.

This initial approach conveys a "feel" for the range of interactivity a CD-ROM might support. For instance, from the table it is readily apparent that In the Desert offers a much richer mix of activities than Food Chains and Webs. The next step involves understanding how these kinds of interactivities support various kinds of learning. Our method for this consists of applying a set of dimensions adapted from our original framework on cognitive interactivity in the light of the teachers' comments in our study. Table 1 shows an outline of this multi-level framework. Most important here are characterisations at the level of what we call "design concepts", which capture the functionality allowed or supported by the software. In the present case we identified the following desirable design concepts from the teacher protocols.

* visibility and accessibility: the interactivity should facilitate inferencing, through directing the learners' attention to key components that are useful or essential for different stages of a problem-solving or a learning task. One way this can be achieved is by the representations used in the CD-ROM (eg, animations, video) making visible what are normally "hidden" processes (eg, visualising carbon atoms moving through the different stages of the carbon cycle).

* manipulability and annotatability: the interactivity should enable the user to develop their understanding of the content presented in the CD-ROM by making changes to it for their own purposes (eg, jotting notes, cutting and pasting images to a notebook). They should also be able to learn through doing, by building new examples, eg, creating their own food chains and webs. Here the idea is that having a better understanding of how to create content (eg, filling in a food web diagram) will enable the learner to have a better understanding of how the system works.

* creativity and combinability: the interactivity should allow the learner to create new content by combining different media (eg, making a multimedia document by recording sounds, building animations). Here the goal is for the user to construct new representations as a way of understanding the concepts presented.

* experimentation and testing: the interactivity should support "hands on" experiments where the learner is required to test out hypotheses in different contexts. Again, these could be experiments which cannot be carried out otherwise in the classroom (eg, test out what would happen to an ocean eco-system if the ocean was polluted). Here the idea is that these kinds of activities should allow the user to run a simulation or build a model that will help them develop a better mental model of the function and structure of a system.

We can now return to the two CD-ROMs, Food Chains and Webs and In the Desert, to illustrate how this approach can be operationalised in practice. Table 3 shows how the design concepts—effectively our indices of interactivity—allow us to ask

questions about the specific features in each CD-ROM. In this way, we argue, a principled basis for comparison is afforded on which educators can make decisions.

CONCLUSIONS

The approach we have developed is intended primarily as a tool to help teachers gain a greater understanding of the value of interactivity in CD-ROMs with respect to learning, and so to enable them to carry out more effective reviews of available educational CD-ROMs. In particular, our method is aimed at moving the emphasis away from the level of physical interactivity at the interface (ie, button presses and mouse clicks) to a consideration of cognitive interactivity (ie, the learning activities which are supported when interacting with the software). Although the method has been developed in the context of primary school science software, the issues and distinctions addressed are relevant to educational software on any topic and at any level. Our hope is that this kind of approach will help teachers (and researchers) to be able to review more effectively and systematically the pedagogical merit of the different kinds of interactivities, eg, interactive quizzes, simulations, games, etc, that are contained in CD-ROMs.

ADDED MATERIAL

Frances Aldrich is a research fellow with the Eco-I project, which is investigating and informing the design of educational interactive multimedia. Yvonne Rogers and Mike Scaife are principal investigators on the project. Address for correspondence: School of Cognitive and Computing Sciences, University of Sussex, Falmer, Brighton BN1 9QH, UK. Email addresses: francesa/yvonner/mikesc@cogs.susx.ac.uk

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Table 1: A theoretical framework of cognitive interactivity (for more detail see Rogers and Scaife, 1997)

At the highest conceptual level cognitive interactivity refers to the interaction between internal and external representations when performing cognitive tasks (eg, learning).

At the next level this relationship is characterised in terms of the following dimensions:

* computational offloading—the extent to which different external representations reduce the amount of cognitive effort required to solve informationally equivalent problems

* re-representation—how different external representations, that have the same abstract structure, make problem-solving easier or more difficult

* graphical constraining—this refers to the way graphical elements in a graphical representation are able to constrain the kinds of inferences that can be made about the underlying represented concept

* temporal and spatial constraining—the way different representations can make relevant aspects of processes and events more salient when distributed over time and space

For each of these dimensions we can make certain predictions as to how effectively different representations and their combinations work.

These dimensions are then further characterised in terms of design concepts with the purpose of framing questions, issues and trade-offs. Examples include the following (others are identified in the text):

* explicitness and visibility—how to make more salient certain aspects of a display such that they can be perceived and comprehended appropriately

* cognitive tracing—what are the best means to allow users to externally manipulate and

make marks on different representations
* ease of production—how easy it is for the user to create different kinds of external
  representations, eg, diagrams and animations
* combinability and modifiability—how to enable the system and the users to combine
  hybrid representations, eg, enabling animations and commentary to be constructed by the
  user which could be appended to static representations

Table 2: Comparing the interactivity of CD-ROMs by listing learner activities

Food Chains and Webs	In the Desert
* watch "slide-show" presentation	* look round 360° panorama
* answer tutorial questions	* click hotspots for into on plants and animals
* do multiple-choice quiz	* go into Visitor's Centre
* look up words in glossary	* visit a school in the desert
* print from screen	* read on-screen books
	* do multiple-choice quiz
	* make music
	* do orienteering activity
	* type notes
	* take "photos"
	* save and print own notes and "photos"
	* print from screen
	* export text

Table 3: Comparing the interactivity of CD-ROMs using our dimensions

Dimension of Interactivity	Food Chains and Webs	In the Desert
Visibility and accessibility	X	X
* visualise content in different ways eg, the invisible made visible		
* access content in different ways eg, multiple views of same topic	X	X
Manipulability and annotatability		
* construct content eg, make new food web	X	X
* make notes	X	X
Creativity and combinability		
* create new content by combining media eg, making a multimedia document by recording sounds, building animations	X	X
Experimentation and testing		
* run a simulation	X	X
* build a model	X	X

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