Exploring the Design Space of Educational Hyper-Systems

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ABSTRACT

The widespread availability of platforms for producing hyper-systems (i.e. hypertext and hypermedia) shows great potential for producing computer based learning environments. However, we do not yet have a great deal of experience in understanding how to make best use of the structural and media possibilities opened up by such systems. This paper explores the issues by analysing the techniques used by designers within a variety of different hyper-systems and begins to develop a space of potential design solutions and their likely impact on learning.

We report the general findings of an expert evaluation of recent hyper-systems. The study produced the following six dimensions: purpose of the hyper-system, domain or content, structure of the nodes and links, navigation methods, control, and style of presentation. These were used to examine the designs more closely using a Design Space Analysis framework and notation known as QOC (MacLean et al., 1991). Performing a retrospective analysis has provided insights about how these dimensions relate to learning from hyper-systems and how the dimensions can influence designs for learning material. We expect that our findings can inform educational hyper-system design.

Keywords: hyper-system, HyperCard, multimedia, evaluation, learning, design, Design Space Analysis.

1 INTRODUCTION

There is considerable interest in the use of hyper-systems (such as hypertext and hypermedia) for education. Some people think hyper-systems have the potential to revolutionise learning. We take the position that understanding current design practice can inform us about how designers view the learning task and thus, their own design goals. In this paper, we present an overview of the results from an expert evaluation of current hyper-systems (Jacques et al., 1992). Using a retrospective Design Space Analysis (MacLean et al., 1991), we investigated the question: what were the designers intentions and why did the they design as they did? This analysis revealed several design goals and provided a way of considering what the alternate designs might have been. Using this technique we can also identify the kinds of trade-offs that designers may make when they have multiple design goals and the implications of both the decisions made and the possible alternatives. In essence, our retrospective analysis can be thought of as a form of reverse engineering. We expect that the findings from our analysis can inform educational hyper-system design.

The paper has two key aims. The first is to emphasise some of the design complexity that educational hyper-system designers confront. The second aim is to demonstrate that retrospective Design Space Analysis provides valuable insight. Before discussing the analysis we shall first set the scene by briefly defining what we mean by a hyper-system and by describing the main task for which the hyper-systems were designed—namely, learning.

2 HYPER-SYSTEMS AND LEARNING

In McKerlie and Preece (1992) the authors argue that while the terms "multimedia", "hypermedia", and to some extent "hypertext" are often used synonymously and interchangeably; the properties of these systems are different. The authors make the following distinctions:

> The prefix "hyper" suggests the notion of branching and decision-making, as in hypertext; a collection of non-linear, text based nodes which are linked together. When multiple-media are added to hypertext, the result is a multimedia system involving branching decisions between nodes of information; in other words, hypermedia: a specialised form of multimedia.

The use of the term "hyper-system" in this paper refers to both hypertext and hypermedia. The kinds of multimedia encountered during our evaluations of hyper-systems include text, graphics, sound, animation, and video. But these definitions are all technological and focus on the medium or technology rather than on the user, who should provide the focus for educational hypermedia design. In contrast Marmolin (1991) offers a useful alternative perspective:

> From the user's point of view, the technology is not as important as the possibilities offered by the technology. A user centred definition would characterise multimedia systems as

(those which enable) the usage of multiple sensory modalities.

Our retrospective analysis of the hyper-systems was driven from a design perspective. We wanted to know how the designers perceived their systems being used and how they took account of different learning tasks such as browsing, searching, navigating and concept learning.

Human factors specialists have advocated the importance of basing design on a thorough task analysis (e.g. Diaper, 1989). A variety of techniques have been developed for the purpose ranging from coarse grain techniques which operate at the department, work-flow, and organisational levels such as OSTA (Eason, 1988), to various forms of hierarchical task analysis, some of which have attempted to take account of cognitive processes as well as operationally decomposing the task. The idea underlying these different techniques is to understand the nature of the users' tasks sufficiently well so that they can be explicitly represented to designers and so that both functional and usability requirements can be identified.

Other techniques also feed into this understanding. For example, usability engineering provides a systematic way of iteratively testing the product during development to ensure that it does indeed meet both functional and usability requirements (e.g. Shackel, 1985, Tyldesley, 1990). More recently, task artefact analysis (Carroll et al., 1990) and other forms of Design Space Analysis techniques such as MacLean et al.'s (1991) QOC notation have been used to analyse design decisions from a usability perspective at different stages of design.

So far, although there is a wealth of literature on theories of learning (e.g. Piaget, 1973), learning styles (e.g. Pask, 1976), and specific studies on problems of learning with various media including computer-based (e.g. Laurillard, 1992) and hyper-system media (e.g. Jonassen and Mandl, 1989), there has been little attempt to analyse specific learning tasks as part of the design of educational hypermedia. There are a number of reasons for this.

One is that most current pedagogic philosophies favour some form of active learning in which the user has some scope to control and chart his or her own learning experience, making the learning task difficult, if not impossible, to define in terms of learning goals and sequential operations. Specifying exactly what learners should do and when they should do it is contrary to the philosophy underlying most hyper-system design. A second reason is that learning is itself a complex task comprising a number of sub-tasks. Most hypertext users browse and search as well as try to acquire new concepts. Wright (1992) made a similar point with regard to reading. She said that it could not be regarded as just one task because people read for different purposes which influence the speed, style, and depth of their reading. A third reason is that learning complex domain concepts depends heavily upon the learners' already existing knowledge in a way that carrying out tasks which are more skill oriented such as word processing, data entry, or information retrieval do not. For these reasons, we suggest that designing hyper-systems for learning is different from designing most commercial systems where it is possible to identify specific tasks and design for those tasks.

Despite the difficulty of defining and analysing learning tasks, hypermedia designers clearly have a notion of what learners should do and learn with their systems. Every hyper-system is based on an implicit model of what the designer thinks the learner will do with that system. However, the facts that users/learners frequently get lost, do not know what they have seen, what there is to see, or how to get there, indicates that the designers' models of these systems are often not obvious to users. The system's image (Norman, 1986)—i.e. those aspects that users perceive through using the system—does not accurately portray the underlying structure of the system.

In order to understand how the system image might appear to learners, what the designers' intentions might be, and how well these intentions are portrayed through the system image, we conducted an expert evaluation (Nielsen, 1989, Molich and Nielsen, 1990) of existing hyper-system artefacts. A summary of the results of this evaluation are shown in the next section. We also used the Design Space Analysis framework and the QOC notation (MacLean et al., 1991) to explore what the range of possible alternative design solutions might have been for some of the particularly interesting features that we observed in the designs. This analysis is presented in Section 4.

3 EVALUATION — METHOD AND RESULTS

Six years ago Apple Computer, Incorporated introduced HyperCard, a programming package containing a scripting language called HyperTalk, based on a metaphor of cards arranged in stacks. As HyperCard was distributed with all Macintosh computers, its user base grew rapidly. Much can be learned about design techniques by surveying the large body of stacks created by this user base.

Our design team of five members performed an expert evaluation on 16 HyperCard stacks, in which HCI experts played the role of typical, inexperienced users. The expert evaluation method is quick, does not involve real users, or the need for specialist equipment; it is a relatively inexpensive method of evaluation. In addition, other methods of usability evaluation often require subjects to perform specific tasks. This would not have been appropriate for our study because it is difficult to set meaningful learning tasks out of context. Knowing the context in which some of these stacks could be used is in itself not trivial; especially as none of the stacks contained any suggestions about how they might be used. Further, in order to remain within the philosophy of hypermedia, any learning tasks that are set need to be sufficiently broad in scope to enable

learners to direct their own learning. Narrowly defined tasks which focus on a particular aspect of use such as browsing or searching can provide valuable insights about design, but give little indication of how the system supports the more self-directed open-ended learning.

As in other expert evaluations (e.g., Nielsen, 1989; Jeffries et al., 1991), we did not attempt to identify all design features or problems. Rather, our intentions were to understand how the users would perceive the design of the systems and why particular design decisions might have been made. Six dimensions emerged from the evaluation and are used here to structure the presentation: *purpose* of the hyper-system, domain or *content*, *structure* of the nodes and links, *navigation* support, *control* over learning process, and style of *presentation*. These dimensions are relevant to both learning and usability issues. The following paragraphs outline the essential aspects and importance of each dimension.

Purpose: the author's intent for the use of the material. This includes the author's reasons for creating the stack and how these intentions are conveyed to users. Most hyper-systems aim to impart some kind of knowledge—from good teaching practice we recognise that learners need to be made aware of learning objectives before they start to work with the material, as exhibited by many well-designed learning materials (e.g. Open University courses)—making clear the purpose or objective of a learning exercise helps to orient the student and helps students to set goals for themselves. Clear objectives are especially important in the case of software, where clues about the content can often be hidden and where disorientation is common. In our evaluation of purpose, we were judging whether or not the purpose was clear from the beginning, and not the actual merits of the purpose itself.

Content: the domain covered by the hyper-system. If the purpose is the author's intent, then the content is the substance which supports the purpose. Hyper-systems in general are extremely varied in their content; indeed, no two stacks evaluated were even remotely about the same topic. We did not compare the contents in isolation, but rather how content was used to support an author's purpose.

Structure: the way the topology of the nodes and links is conveyed to the user. From our knowledge of books, we understand the importance of structure when conveying ideas. Even linear books embody structure. Within non-linear material, such as hypertext and hypermedia, structure is equally, if not more, important. Indeed, one of the goals of hypertext and hypermedia is to show relationships between isolated, fragmented, or encapsulated ideas. These relationships form a structure. It follows that, for the user, understanding the structure is important for learning about the content. We identified a set of structures and examined how they might appear to users.

Navigation: tools and techniques available for taking links and making link decisions. The process of navigating enables users to experience the content material. Navigating also reveals the relationships between ideas because it effectively enables users to traverse the structure. We found that navigation aids (such as maps and table of contents tools) provided similar functionality across hyper-systems, but with variable results. McKerlie and Preece (1992) list seven questions to which the answers are fundamental for successful navigation (e.g. where am I?, how did I get here?, what have I seen so far?, etc.). This suggests that merely enabling users to take links is not enough; users require support for helping them to make link-taking decisions if they are to direct their own learning. We identified a variety of navigation tools and evaluated the support they could provide.

Control: provision for allowing users to exercise control. Being in control has implications for giving users the confidence and means of controlling their own learning. With respect to interaction, designers know that in most cases humans, not computers should control the interaction dialogue (e.g. pace, direction, quantity, etc.). The amount of control that users take over their own learning depends on many circumstances such as the students' learning style, subject matter, level of the users' understanding, goal of the learning exercise, etc. We looked for mechanisms which enable users to take control of the interaction dialogue and hence to exercise control over their own learning.

Presentation: the style in which the content is conveyed. Presentation issues include the style and use of text, graphics, sound, animation, and video. In different design fields, there are established practices for presenting information via a particular medium (e.g. typography describes characteristics of text such as legibility). What appear to be lacking in hypermedia design are established rules or heuristics for matching content with medium type (e.g. actions may be better conveyed through video than text). As researchers and developers gain more experience with hypermedia, design heuristics are likely to emerge. Better development tools and improved technical capability will also influence development of heuristics. As a first step to understanding the match between content and presentation, we identified the effect, impact, and potential success of different presentation styles.

The following five stacks are referred to in the remainder of this paper to illustrate the findings from this evaluation and for further analysis:

- **2-Stroke Engines** (copyright Barry McLarty, 1991)**:** a stack of 79 cards, arranged into five subject areas and a multiple-choice questionnaire. It aims to teach students about the principles of 2-stroke motorcycle engines.

Hyper-System	Purpose	Content	Structure	Navigation	User Control	Presentation
11/22/63 EXTRA	argument	evidence in the form of movies, text sound, and photographs	shallow hierarchy and linear paths	next, previous, return, first card	high user control, well integrated with content	graphics & text with dramatic use of video & audio
Introducing Microsoft Excel	tutorial	example-based training material	shallow hierarchy and linear paths	forward backward	simple user controls but low self-directed learning	screen shots of actual presentation mixed with descriptions
XIIth Night	experience	artistic vignettes	broad & shallow set of multiple paths with linking	device based on metaphor of a theatre	very little user control	extensive and exceptional graphic design
Celtic History Museum	interest	artefacts	hierarchical with some links	maps	high user control	attractive use of scanned photographs combined with text
2-Stroke Engine	demonstration	animation's	linear	forward and backward, animation controls	high user control, reasonable self-directed learning	clear animation

Table 1: Summary of evaluation approach and results.

- **11/22/63 EXTRA!** (copyright Brian Thomas and riverTEXT, 1991): a stack of 44 cards arranged into three main areas. It attempts to convince the user of erroneous conclusions concerning the assassination of President Kennedy.

- **XIIth Night** (copyright Xploratorium, Anglia Polytechnic, 1991): a CD-ROM product arranged into 7 subject areas about the life and times of Shakespeare and the play, XIIth Night.

- **Celtic History Museum** (1991): a stack of 209 cards arranged into the layout of an imaginary museum with eight exhibition halls.

- **Introducing Microsoft Excel** (copyright Microsoft Corporation, 1991): a stack of over 100 cards, arranged into two areas aimed at introducing novice users to the software application, Microsoft Excel.

Table 1 summarises the high-level differences that were observed between the five example stacks. The evaluation of the remaining 11 stacks revealed similar findings (See Jacques et al., 1992, 1992a for further details).

4 DESIGN SPACE ANALYSIS AND DISCUSSION

The intention of the discussion that follows is to amplify some of the points in Table 1 and, by further analysis, to explore the design spaces surrounding these hyper-system examples. Our aim is to inform hyper-system design by understanding the reasoning behind the design decisions represented by this collection of hyper-system artefacts. The results of this retrospective analysis are currently being applied to our own educational hypermedia design project.

We will focus here primarily on the design of two stacks, **11/22/63 EXTRA!** and **Celtic History Museum,** as well as draw upon examples from the other three stacks to illustrate alternative approaches to hyper-system design.

The retrospective analysis made use of the Design Space Analysis framework and a notation known as QOC for Questions, Options and Criteria (MacLean et al. 1991). In the discussion of our findings, we will include examples of this notation. In some respects the analysis can be regarded as a form of reverse engineering

since we analysed the designed artefacts in order to understand and describe why they were designed as they were. Obviously, such suggestions have to be regarded somewhat tentatively as we do not know whether the designers considered the various objectives, alternatives, or justifications that we propose. There may, for example, have been subtle, difficult design trade-offs which are not obvious. Even so, the analysis has revealed several interesting findings. These will be addressed with respect to the six dimensions described in the previous section. One interesting feature of this analysis which we have already mentioned is the need for educational designers to take account of specific criteria such as motivating students, as well as the task of learning (which, as we have already said, is composite and difficult to analyse).

4.1 Purpose

Although all the hyper-systems were designed to provide some form of education, a variety of different purposes or objectives of the hyper-systems were identified which were not always successfully conveyed to potential users.

Introducing Microsoft Excel, for example is a stack that delivers training material in a didactic tutorial form. The **2-Stroke Engine** stack explains the mechanics of a motorcycle engine through an animated demonstration of the engine's function. A more artistic and exploratory style is exhibited by the **XIIth Night** CD-ROM disk which encourages users to explore the life and times of Shakespeare through an experience of sounds, text, and high-quality graphics. In contrast **Celtic History Museum** aims to generate interest in a culture through a collection of historical artefacts. **11/22/63 EXTRA!** attempts to argue a particular point of view by presenting concrete, physical pieces of evidence which are woven together to confirm the author's opinion. The end result is a presentation of a theory, something which is conceptual by nature, through the use of integrated visual and auditory media.

Using the QOC notation, these different learning purposes can be summarised as shown in Figure 1. In this diagram the Question that is being addressed is *what is the purpose?* The various Options that were observed in the five stacks (summarised in table 1) are: *argument*, *tutorial*, *experience*, *interest*, and *demonstration.* From these observations we can deduce the kinds of learning experience that the authors of the stacks intended for the users and these are shown as Criteria in the diagram. The QOC notation uses solid lines to represent positive assessments of Options by Criteria. Broken lines are used to show that a Criterion is not supported by an Option (negative assessment). Note that the assessments of Options against Criteria are *relative* comparisons among the set of Options and specific to the hyper-systems that were evaluated.

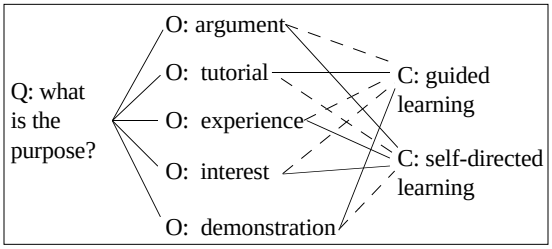

Figure 1: QOC diagram showing the purpose of the stacks and how these relate to a guided or self-directed learning experience.

Our evaluation also indicated that an effective title can provide valuable up front information about the purpose of the system. For example, the title **Introducing Microsoft Excel** suggests that the stack is not particularly suitable for experienced Excel users, but rather more suited for novices. In contrast, the title **11/22/63 EXTRA!** provides few clues about the authors' intentions, but could draw in naturally curious users, so here we have an example of the designer having to make trade-offs between two intentions—to convince users of a particular argument and to entice the curious to use the stack.

Our retrospective QOC analysis enables us to reflect upon what the various Options might have been and, in some cases, to postulate why particular decisions were made. Figure 2 shows this use of QOC for selecting a title for **11/22/63 EXTRA!** This diagram suggests that revealing the intended purpose of the stack to the users through the title is indeed not the most important consideration.

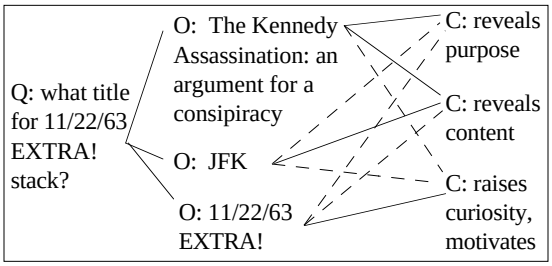

Figure 2: QOC diagram for selecting a title for **11/22/63 EXTRA!**

In addition to the title, the first card is also used to convey information about the objectives or purpose of a hyper-system. The design of the first card for **11/22/63 EXTRA!** (see Figure 3) also appears to focus more on motivating and enticing users, than on conveying the stack's purpose.

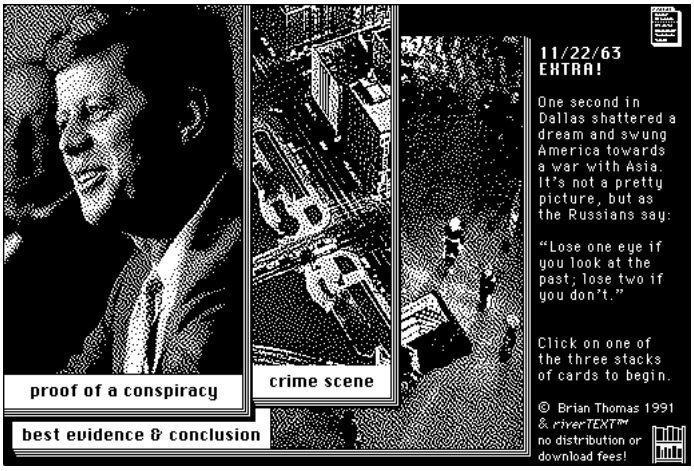

Figure 3: First card from **11/22/63 EXTRA!** stack

In contrast, the **Celtic History Museum** uses a straightforward but powerful approach: the metaphor of a museum. From the title alone, we can make the assumption that the author intends it to be museum-like. That is, we can imagine ourselves as users, browsing through museum-like artefacts, gaining an appreciation for and an interest in Celtic history. However, the design of the first card (Figure 4) provides a good contrast to Figure 3.

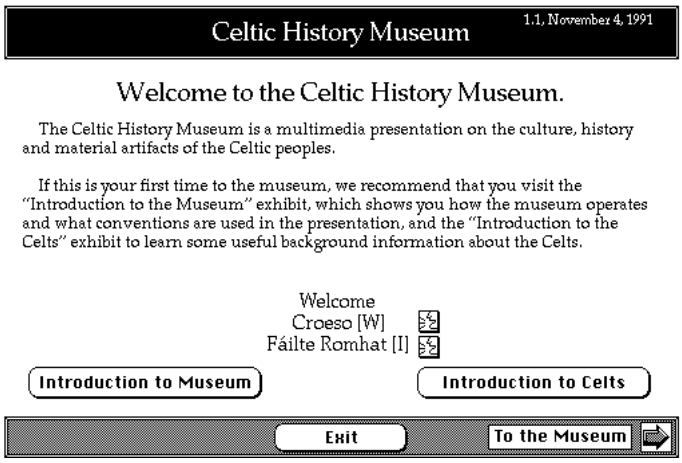

Figure 4: First card from Celtic history Museum stack.

Perhaps this designer did consciously consider the need for motivating users but decided that the visual nature of the content was sufficiently aesthetic and interesting to entice users. A comparison of the design style of these two first card examples is given in Figure 5.

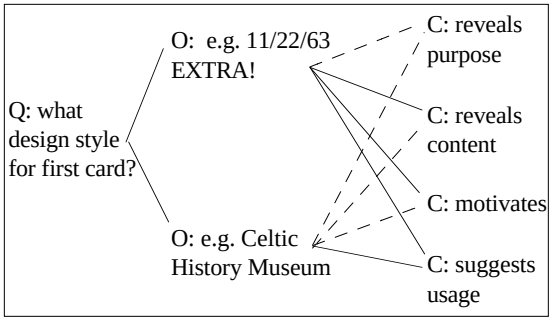

Figure 5: QOC diagram comparing the design styles of the first cards from **11/22/63 EXTRA!** and **Celtic History Museum**.

Whatever the authors' purpose, it is helpful for learners to know what this intention is and also to be given information about the basic learning objectives that the author expects the user to have. However, as we have shown, authors of learning material may make design decisions to meet less explicit goals such as motivating or engaging learners rather than making the purpose of the stack explicit. This approach adds complexity to the design of learning systems which is not relevant in other commercial systems (such as word processors). Whether or not employing this tactic is successful can best be judged by real users.

4.2 Content

We have considered the content in relation to how it substantiates the authors' purposes or intentions. **11/22/63 EXTRA!**, for example, is about the assassination of President Kennedy which, from the title alone, will be obvious to only a selected set of users. While the title may not reveal much about the content, the first card (Figure 3) certainly does. The graphical design displays scanned black and white photographs describing the content. Kennedy is prominently in front, a view of the crime scene is partly visible behind Kennedy, and behind that is an aerial view of his coffin (almost as though Kennedy may himself be looking down on it). The black and white photographs create a sense of history and tell a story in themselves. The photograph labels suggest what is to come.

We have described the purpose of the **11/22/63 EXTRA!** stack as to build an argument and convince the user of a particular point of view. This purpose is supported in the content by the collection of factual evidence and conjectural opinions. The authors use a metaphor which is recognisably, though not obviously, journalistic. It is characterised by a newspaper style layout, an objective approach to presenting facts, and a case-building approach for conviction. By adding sound and video however, the bounds of the metaphor are pushed. The result is somewhat like a news report documentary on your desktop. From an educational point of view, learners are invited to discover the alternative theory about what actually happened for themselves.

In contrast, the first card of the **Celtic History Museum** (Figure 4) is not suggestive of the content. While the content revolves around a museum metaphor—including pictures of artefacts with accompanying explanations—the first card is a series of textual instructions; not particularly reflective of the content. What might the alternative designs be which support or reflect the content better? Figure 6 shows some suggestions.

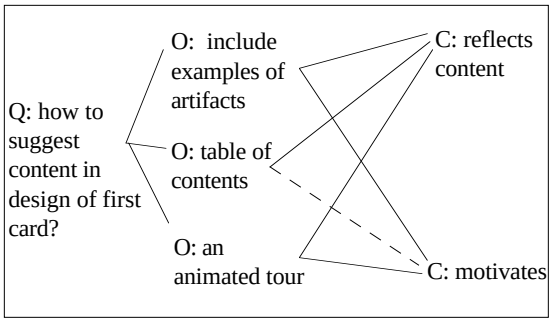

Figure 6: The design of the first card in the **Celtic History Museum**

4.3 Structure

Understanding the structure of a body of material helps the user to build a mental model (Norman, 1986) of relationships within the content, which supports learning. The stacks adopted different methods of structuring, with varying degrees of complexity. The simplest structures are linear sequences of cards forming a single loop, which are easy to comprehend but rather restrictive. Most of the hyper-systems employ a more complex hierarchical or network structure, with varying degrees of success.

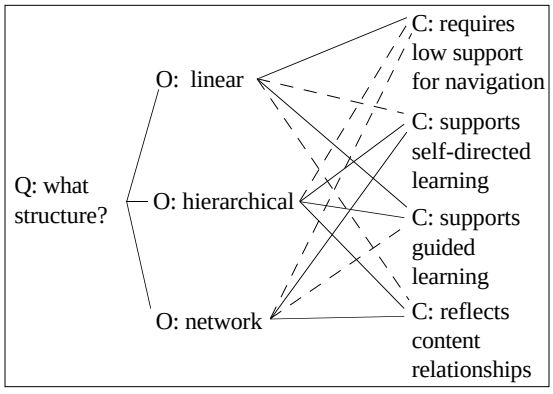

Figure 7: QOC for different stack structures to support learning and usage

The obvious trade-offs between linear structures and hierarchical or network structures are ease of navigation versus flexibility and additional complexity. Hierarchical or network structures can convey the relationships among ideas in the content and provide users with opportunities to direct their own explorations of the content. In addition, we found them to have more adventurous, appealing, and engaging qualities, which are important for motivating learning. However, such structures require more navigational support than simple linear structures. Figure 7 suggests how the three kinds of structures support learning and usage.

4.4 Navigation

Effective navigation through a hyper-system requires a sound navigational system closely tied to its underlying structure and its content. Ideally, users should be able to navigate efficiently to a particular card or return to one they have previously been at, find a particular piece of information, or to simply browse through nodes. We suggested earlier that navigation is successful when users can answer questions like: What can I do here? Where can I go? How do I go there? What else is there for me to see? To facilitate these requirements, hyper-systems can employ a variety of different navigational aids or tools.

One particularly effective technique is the Table of Contents tool in **11/22/63 EXTRA!,** which provides a set of cascading menus of each card in the stack (see Figure 8).

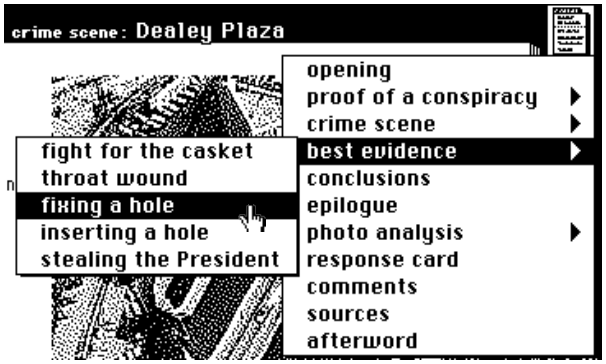

Figure 8: Cascading Table of Contents tool in the **11/22/63 EXTRA!** stack.

Its primary function is to give navigational support to the user. In addition, because the card titles are identical to the table entries, the mechanism can answer the question "where am I?" within the structure of the stack. It also provides information about where the user can go and how much information there is altogether. As the stack already provides adequate manoeuvring mechanisms (e.g. forward, backward, back-to-beginning-of-deck, and back-to-title-card), the Table of Contents is an added, alternate, navigation tool which provides both redundant and added functionality.

The icon used to represent the Table of Contents tool had several good properties (visible in the top right corner of Figure 8). It is small and unobtrusive; giving the correct impression that it is not an appropriate beginning point, but rather something to explore after the user has reached some familiarity with the content material.

Options	Criteria				
	where am I?	how did I get here?	what can I do here?	how much is there? how much have I seen?	where can I go? how do I get there?
maps	+	+	—	+	+
tables of contents	+	—	—	+	+
tours / agents			+		
sign posts	+	—	—	—	+
typed links	—	—	—	—	+

Table 2: QOC assessment of navigation tools (Options) against the properties of successful navigation (Criteria).

How might alternative forms of navigation been used? One observation is that the context for different solutions is important. For example various forms of maps were used to support the museum metaphor in **Celtic History Museum** (see Jacques et al., 1992, 1992a). What might a table of contents have contributed to the **Celtic History Museum** stack and conversely, what might a map have contributed to **11/22/63 EXTRA!**? Table 2 shows our analysis of possible navigation tools to support the essential properties of successful navigation. The table format is a more concise variation on the QOC notation: "+" signs indicate a positive assessment of the Options against the Criteria and "–" signs indicate a negative assessment. Blank entries indicate that more specific information is necessary (e.g. about users or specific designs) in order to make this kind of assessment.

4.5 Control

Authors of hyper-systems make assumptions about how users will conduct an interactive session and about how users will learn. In both cases, user control is an issue. We can assume that users prefer to be in control of the interactive session. In education however, there are conditions under which it is useful for authors or teachers to retain some degree of control over the dialogue in order to provide guidance in the learning process.

In several of the QOC examples so far, we have used the Criteria *self-directed learning* and *guided learning* to describe a continuum between enabling users to direct their own learning process and enabling authors to retain control over the learning process in order to guide the student user. This issue of control is particularly relevant to educational hyper-system design since there may be a tension between control in the sense of usability and control in the sense of teaching.

For example, **Introducing Microsoft Excel** attempts to teach users about a software package. The interactive control mechanism is simple: forward and backward buttons which provide adequate functionality to control the interactive session. However, the design has enabled the authors to "guide" the learning process to the extent that the student/user has relinquished nearly all control over the learning process. Because of this, we have judged it to be a less than effective learning tool.

4.6 Presentation

There is no question that presentation style (i.e. choice and combination of media) is often what users notice first about a hyper-system. However, our conclusion about presentation style is that successful hyper-systems are only as good as their underlying material and organisation. In other words, exciting use of graphics and sounds really only make an impact on systems which are already well designed. A problem which design teams face is the choice of appropriate media for particular information and particular user tasks. With this in mind, we attempted to identify the effect, impact, or success of particular choices of presentation styles.

There were several good examples of the use of graphics and colour (especially in **XIIth Night**). However, the use of sound, animation, and video were somewhat lacking. Video was used successfully in **11/22/63 EXTRA!** where a QuickTime movie of the actual footage of the assassination is included. Many people have seen it before, but this stack gives the user an opportunity to play the clip forward or backward, in fast or slow motion, or one frame at a time and at any size; a novel opportunity. In most cases, sound was used to provide ditties and special effects; a useful technique for keeping users' attention but one which could get annoying. A particularly interesting use of sound was again exhibited by **11/22/63 EXTRA!**. The stack makes use of several audio recordings of actual events. The impact of hearing the gunshots and the ensuing commotion is far greater than having them described through text or a third party. Other examples of different uses of media are discussed in Jacques et al., 1992, 1992a.

We identified the problem earlier of knowing which media to use for different kinds of information. From the examples in **11/22/63 EXTRA!**, it is apparent that use of sound and video which record actual events is very effective. This is in contrast to "gratuitous" video (e.g. talking heads) and sound (e.g. voice buttons) which do not have the same striking impact.

It is interesting to consider how these designers decided on different media. Analysing this part of the design is problematic; we can examine what each of the different media contribute (see the QOC analysis in Table 3) but the media are being used in combinations—perhaps the whole is greater than the sum of the parts (McKerlie and Preece, 1992) in that it creates mood, expectation, or a sense of being there. Unfortunately, our QOC notation needs to be supplemented by sketches or mock-ups to enable us to experience the alternatives—this could have been done during the actual design and would have been useful (see for example, McKerlie and MacLean, 1993 for a discussion of this approach), but it is too rigorous to attempt as part of our *post hoc* analysis.

Options	**Criteria**			
	available at hand	provides clear argument	low reading on screen	can illustrate idea
full text	+	+	—	—
point form	+	—	+	—
voice-over & sound	+	+	+	—
video	+	+	+	+
graphics	+	—	+	+
reference to paper source	—	+	+	+

Table 3: The use of media in the first card of **11/22/63 EXTRA!**

5 CONCLUSIONS

We have suggested that designing educational hyper-systems is difficult for two reasons. Firstly, defining learning tasks is not straightforward and the flexibility inherent in hyper-systems makes task analysis even more difficult. Secondly, educational hyper-system designers often have to make trade-offs in order to satisfy several design goals. For example, not only must they design for the learning task but they must also think about strategies to motivate learners.

These problems can be alleviated by recognising them within a particular context and understanding the range of potential design solutions. Both experienced and inexperienced designers can benefit from reflecting on their own and others' design artefacts. Our retrospective Design Space Analysis, for example, illustrated how different designers dealt with the trade-offs between designing for the learning task and designing to motivate learners. The QOC notation provided a vehicle for thinking about and presenting the analysis, as well as for examining possible alternative solutions both within the design of a single system (i.e. *intra* design analysis) and for comparing the approaches used in different systems (i.e. *inter* design analysis). These analyses make the trade-offs between alternative solutions obvious, which enable designers to consider how each alternative would serve within *their own context*. This last point is important—since each design context will be different and will be influenced by such factors as: the nature of the learning intended, the content domain, and the development platform.

In the analysis, we examined how six design dimensions were represented in the hyper-system artefacts: the designer's purpose for creating the stack, the content, structure, navigation, control, and presentation. A conclusion that we can draw from our analysis is that, although a wide variety of different design solutions are exhibited in the stacks that we examined, the way the purpose of the stack is portrayed in the first few cards influences how the learning experience will be perceived. Further, understanding the organisation of content is important for learning, so both structure and navigation play key roles in educational hyper-system design. In addition, we found that control has implications for the learning process and the influence which educators can have in guiding student users. Finally, making effective use of media choice for presenting content can add substantially to the learning experience. However, we continue to lack heuristics for making decisions about which medium to use for which kind of material.

Our retrospective Design Space Analysis has helped to make important design considerations explicit, which has provided us with a starting point for considering the many complex design issues that we face in our own project. State-of-the-art hyper-system design is in its infancy and the development of new data types and better delivery platforms will bring about many changes over the next few years. Designers will need guidance on how to capitalise on these innovations in order to design meaningful learning experiences for users. This kind of analysis can contribute to the development of much needed *high-level* design principles and bring awareness about how they apply in different design contexts. Designers can then benefit by applying the principles in a meaningful way to their own designs.

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