Digital Libraries:
A Conceptual Framework

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This article presents an approach to a conceptual framework for understanding the concept of digital libraries. A typology of digital library research is described, based on Yates' model of information work, and comprising three inter-linked domains: informational, technological and social. A conceptual framework for digital libraries, or complex libraries in Walt Crawford's (1999) terminology, is developed on this basis.

Introduction

The purpose of this paper is to propose and partially validate a high-level conceptual framework to aid in the better understanding of the idea of 'digital library'. It builds upon the examination of concepts, terminology and assumptions presented in an earlier paper (Bawden & Rowlands 1999a). Both papers are based on a report commissioned by the British Library Research and Innovation Centre (Bawden & Rowlands 1999b), but extend the scope of the material presented there, and include material not available when the initial report was prepared.

The value of conceptual frameworks

As the digital library concept becomes more firmly embedded and assumes greater significance for public and organisational information policies and strategies, so does the need for a higher level framework to organise our understanding of these developments become more pressing. Frameworks of the sort developed here may be used to accomplish the following:

- compare and evaluate the outcomes of digital library initiatives;
- translate research findings, and experience in practice, in one country or sector to another;
- help to define areas where further research is needed, and to guide research strategies;
- help to identify hidden linkages and synergies between different research areas;
- help bridge the 'conceptual gap' between research and practice;
- help to tease out the policy implications of digital library research.

There is a close link between the frameworks used here, and certain kinds of conceptual models

Simply defined, a model is anything which represents those parts of reality considered for some purpose. It stands in the place of reality in order that we can think, negotiate, play or experiment (Underwood 1996).

The aim of this work is to use a model for thinking or, more precisely, for *understanding*; understanding the meaning and relations of concepts. Such a model will necessarily be at a high

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level, and will deal with general ideas, rather than detailed processes or structures/products.

Models and frameworks are more important in the real world than is sometimes acknowledged, since they shape the way we look at reality and frame the language we use to describe it. John Maynard Keynes wrote "practical men, who believe themselves to be quite exempt from any intellectual influences are usually the slaves of some defunct economist". In attempting to simplify the complexities of the digital library, we have necessarily been highly selective about those aspects of reality we have decided to project and emphasise and those we have played down.

Models of this sort have had limited application to the digital library area, though Brophy (1999) points out the value of models for the digital library in establishing the linkages between functions, and in providing a holistic view. Brophy and Fisher (1998) note the obsolescence of a 'holdings' model and the inadequacies of a 'systems' model, and favour a view of the library as an 'expert intermediary' between users and information (see also Lagoze & Fielding 1998). Most models have largely taken the form of system and function block diagrams (see Brophy (1999) for a comparison of several). An alternative simpler form of model has been one that presents alternative conceptual views of the digital library. For example, there is Borgman's (1999) three-way view:

- digital libraries as content, collections and communication;
- digital libraries and institutions or services;
- digital libraries as databases.

A still simpler form of model is the metaphor, a number of which have been used with respect to digital libraries, 'hybrid' library being the most obvious. A newer metaphor is the information 'landscape' or 'ecology', discussed with respect to the digital library by Lynch (1999) and by Dempsey (1998).

The scope and structure of digital library research

An initial review (1) of the scholarly and professional literature relating to digital library research revealed eight thematic clusters:
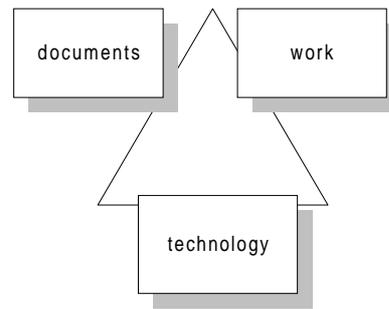

Figure 1: Yates' work-oriented library model

- human factors;
- organisational factors;
- library management factors;
- information law and policy factors;
- systems factors;
- knowledge organisation and discovery factors;
- impacts on the information transfer chain;
- futures studies and scenarios.

These clusters reflect contrasting approaches to the study of digital libraries and the highly multi-disciplinary nature of the research questions posed. The conceptual framework that we develop here recognises that diversity by adopting a work-oriented perspective based on the work of Yates (1989). Yates (see Figure 1) highlights three crucial aspects that may be applied to the understanding of both traditional and digital libraries. Libraries, however much they differ outwardly, have one thing in common: they house and provide access to stores of *documents,* defined in the broadest sense to include enduring communicative records. These documents are created and maintained using *technologies* that have required considerable human investment to develop – from the printed book to the object-oriented database. And both documents and technologies are deployed through the institution of the library to support *work* – both the work of the researchers who use the library and its own staff who provide reader and other services.

This simple framework emphasises the interconnectedness of documents, technologies and work, and stresses the fact that technological advances are not the only sources of innovation in the digital/complex library.

Levy and Marshall (1995) examine the consequences of Yates' model for the digital library. Technical infrastructure does not, in and of itself, constitute a digital library. That requires content – more specifically, managed collections of content for identified user communities. The major issues in the evolution of the digital library: interoperability, scalability, deep semantic retrieval, preservation, etc., can all be seen to be highly dependent upon solutions which draw in a coordinated fashion from the worlds of documents, work and technology.

Other writers seem independently to have reached a broadly similar conclusion

> Digital libraries are best thought of as human resource streams that unite readers, authors, librarians and researchers with electronic materials, resource streams, computer equipment and know-how (Covi & Kling 1996).

> By stressing the importance of either technology or librarianship, commentators on the digital library have created a false dichotomy; digital libraries need librarians in partnership with domain and information technology experts (Matson & Bonski 1997).

In this paper, the three elements of Yates' model have been re-labelled as the *informational* (documents), the *systems* (technology) and the *social* (work) domains of the digital library. These domains offer a more meaningful grouping of the thematic clusters identified earlier, which are now more clearly seen to be overlapping:

Social domain

- human factors (non-machine specific);
- organisational factors;
- library management factors;
- information law and policy factors;
- impacts on the information transfer chain;
- futures studies and scenarios.

Informational domain

- knowledge organisation and discovery (e.g. metadata);
- impacts on the information transfer chain (e.g. supply);
- futures studies and scenarios.

Systems domain

- human factors (e.g. human-system interaction);
- systems factors;
- knowledge organisation and discovery (e.g. software agents);
- impacts on the information transfer chain (technical);
- futures studies and scenarios.

We now make an attempt to summarise the key issue evident in the recent professional literature on the digital library, beginning with social factors, in the belief that many current digital library developments unduly emphasise questions of what? and how? rather than why? It is notable that much digital library research has been confined to a single domain, and it may be that this has contributed to the confusion of concepts, and deficiencies in practical implementation.

Research in the social domain

Research into the social contexts surrounding the digital library (here defined broadly to include psychological, cultural, organisational, economic, legal and policy elements) is characterised by high disciplinary and literary scatter. These are considered here under four main clusters of research effort:

- information skills and literacy;
- impacts on the nature of work;
- impacts on organisations;
- information law and policy concerns.

Information skills and literacy

The advent of the digital library carries with it a need to re-assess what the notion of literacy really means at this point in history. The term carries wide variation of meaning, and a considerable overlap with other terms, such as library literacy, network literacy and, most recently, digital literacy (Bawden 1999). It can, however, best be understood as a complex of skills and attitudes, involved in accessing, evaluating and using information, where the information may well be obtained from a variety of sources and in a variety of formats. Such skills are of evident ne-

cessity in the complex environment of the digital library; conversely such an environment is a rich arena for developing such skills.

A consensus seems to be emerging that learning in digital library environments encompasses two distinct components: learning how to access, evaluate and use information resources; and learning how to master and build on the ideas embodied within those resources. In its most highly developed form, information literacy has been characterised by "free form learning and just-in-time information delivery" (Weinberger 1997).

Impacts on the nature of work

An assumption, sometimes explicit, more usually implicit, informing the design of the digital library is an idealised form of use: the lone researcher sitting at a workstation. The origins of this conception probably derive by extension from client-server architectures and the ordered world of systems thinking. Yet we know by observation and from experience that information seeking, research activities and library service are often highly collaborative. Ehrlich and Cash, for example, note that

> People seek information by communicating with members of their communities; they look not only for materials and specific answers, but for corroboration, new interpretations, and new methods of finding information ... all this suggests that support for communication and collaboration is as important as support for information-seeking activities and that, indeed, support for the former is needed to support the latter (Ehrlich & Cash 1994).

The social implications of the digital library are profound. Digital technologies relax the constraints of time and place in relation to how people work with one another. New organisational forms are beginning to emerge, such as *collaboratories*, but the ultimate effects of these new ways of working are unknown. While some advocates of the digital library see the elimination of the library as place, this now seems an increasingly extreme – and technologically determinist – position to adopt.

Methods for selection, acquisition, organisation, access and preservation in the digital library differ considerably from those in traditional libraries and models of best practice need to be devel-

oped and promulgated. The focus among library consortia is gradually shifting from integrated library systems to digital library projects, resource sharing, collective database licensing and document delivery, each of which implies considerable changes to working practice. Indeed, some of the more alarmist pronouncements on the virtual library foresee the elimination of intermediaries (search intermediaries, librarians, retailers, distributors and others) who merely 'interfere' in the process of interchange between content creators and readers.

Finally, the fragility of cultural memory in a digital age should not be underestimated. There are many thorny issues associated with the obsolescence of digital media, the migration of data to other hardware and software platforms or generations, and legal and institutional barriers. This aspect has caused concern to many commentators:

> The difficulty and expense of preserving digital information is a potential impediment to digital library development. Digital preservation is largely experimental and replete with the risks associated with untried methods. Digital preservation strategies are shaped by the needs and constraints of repositories rather than users, current or future (Hedstrom 1997).

The term digital preservation is used two meanings, somewhat distinct: the preservation of materials created in digital form and the digitisation of analogue materials for access and preservation. The preservation of materials in the digital context is more complex than in a traditional library, and involves several aspects (see, for example, Hedstrom & Montgomery 1998). These will ideally be incorporated into life-cycle management of digital information, from creation through storage, migration, and continuing access for so long as the resource is deemed to have value. Necessary tasks include not merely physical preservation. They also include the copying of digital materials in their original format from old to new media of the same nature to prevent physical deterioration (*refreshing*); the periodic transfer of digital materials from one system (hardware and/or software) to another, or from one generation of computing equipment to the next, to prevent technological obsolescence (*migration*); and possibly also the archiving of equipment.

Impacts on organisations

The impact of the digital library on existing institutions and institutional structures is another focus of serious interest, not least in relation to the future role and place of traditional libraries. Positions on this issue range from those held by *transformists* who foresee the disappearance of the physical library and its phoenix-like re-manifestation in completely virtual form, to *continuists* who stress resistance to change, inertia and 'more of the same'. The critical factor in this equation is people

> Digital library proponents must consider the role of people (as users and service providers) if the digital library is to be truly beneficial. Technology and information resources, on their own, cannot make up an effective digital library (Sloan 1998).

The culture change implied is something more than merely a change in routine, or in the particular tasks to be done; rather this implies a more far-reaching change of ethos and values, reflecting in a need for new skills, knowledge and attitudes. This may include users becoming more self-reliant in their information seeking and using behaviour, while librarians will become providers of systems, resources and interfaces. This, however, may be an oversimplification of the situation, ignoring for example the role of the library in providing a focal point in organisational, local, and national life (Tsuno et al. 1998, Collins 1998).

Information law and policy concerns

The migration to an increasingly digital library infrastructure throws up many legal and policy issues widely discussed in the literature. These relate, *inter alia,* to information integrity; document authenticity; user confidentiality; user authentication (Lynch 1997); payment systems; security; encryption and personal privacy; and, not least, copyright management (Mann 1998).

Digital libraries are evolving in a policy vacuum and against a background of great uncertainty. While it is clear that there is a need for focused research into specific issues such as rights management, data privacy and digital signatures, the 'policy regime' (Braman 1990) – an overarching set of principles and values providing a common framework of understanding – also needs to be addressed from a digital library perspective.

Research in the informational domain

Research within this domain has been focused on various aspects of resource description and subject access:

> Information exploration in digital libraries involves building bridges between document space (the realm of information artefacts, ranging from books to e-mails to bibliographic references) and concept space (the context and knowledge required to interpret documents) (Baldonado 1999).

This concept of 'information exploration' subsumes a number of inter-related activities

- accessing;
- searching;
- browsing;
- navigating.

These terms are used loosely in the literature. Generally access is taken to be the broadest term, implying both physical access – the resource is available by technical means – and authorisation – the user is permitted to access it.

Searching generally implies a purposive identification of items by criteria, subject or otherwise, which are clear to the user. Browsing and navigating, usually but not invariably, imply a more loosely structured approach. Although more detailed typologies of searching and browsing are described (Bawden 1993, Large, Tedd & Hartley 1999), they do not seem to have been much used in studies of digital libraries, an exception being the writings of Bates (1998).

Metadata, and resource description, is of central importance. The term metadata was, apparently, first used in the literature in 1962, and made its first appearance in a dictionary in 1980 (Bide 1999). Metadata is contentious because its function is perceived very differently by librarians and computer scientists; the perspectives of bibliographic control and data management respectively (Ng et al. 1997). A rich metadata structure is required in a digital library, with three functional categories, at the descriptive (or intellectual), structural, and administrative levels, the library cataloguing approach to metadata addressing only the intellectual level. Metadata standards are starting to emerge that may be-

come to digital libraries what MARC has been, and still is, to print libraries, the most notable contender being Dublin Core (Dempsey & Heery 1998).

Information retrieval in distributed network environments poses other challenges. The most notable of these is the degree to which information retrieval can be made to operate at the level of meaning (semantics), rather than character matching (syntactics) across large heterogeneous document collections. "Deep semantic interoperability" is a phrase that often crops up in digital library vision statements, but precisely how we get there is far from trivial.

Evaluating the performance of information retrieval systems in distributed environments is another area of concern, since it is clear that precision and recall offer far from adequate measures of retrieval effectiveness. New metrics, perhaps based on the structural analysis of hypermedia networks and the browsing and navigational behaviour of users need to be developed and tested (see, for example, Salampasis et al. 1998, Buttenfield 1999, Chowdury & Chowdury 1999).

Research in the systems domain

The two issues that stand out most clearly in research and development in the systems domain are interoperability and scalability. Co-ordinated progress in both areas is needed to deliver Hunt & Ethington's vision of digital libraries that gives

> ... full realization of the potential for infinite, integrated growth in materials, genres and formats (Hunt & Ethington 1997).

One reason that the question of interoperability has received such wide attention is that the problem permeates almost all aspects of digital libraries that offer distributed access to diverse materials and formats. Interoperability has implications for systems architectures, standards and protocols for data transfer, metadata, and mark-up languages (Paepcke et al. 1998, Cole & Kazmer 1995, Healy 1998).

The notion of interoperability therefore summarises a wide variety of needs and procedures, requiring integration at a number of levels, from physical connection of equipment, through standard for format interconversion and resource naming, to the intellectual interoperability of

metadata between resources. Brophy and Fisher (1998) distinguish five levels of interoperability: technical, semantic, political, inter-community and international. Brophy (1999) adds accessible interoperability. Digital libraries of the future will inevitably be shaped by the technologies, standards and models adopted today (Tennant 1997).

The scalability of digital libraries, potentially to national and international dimensions, is only possible within the limits set by interoperability standards (or the lack of them); the effort required to support a scaled-up service might also be a factor:

> Experience shows that failure to scale is one of the most frequent reasons for failure to turn electronic library experiments into viable services (Brophy and Fisher 1998).

The future of digital libraries?

There are many competing visions of what the digital or virtual library will look like. One thing that is certain is that the digital libraries of the future will be shaped by the technologies, standards and models adopted today. Some commentators believe that current directions in digital library research and development are too conservative in some respects.

> Discussions of the digital library usually emphasise the transition of scholarly information and libraries to the electronic medium. To that extent, the discourse is framed in the context of the print world we all understand. Most of the attempts to build 'digital libraries' build on these analogies. On the other hand, it is likely that this thinking about 'transition' is itself transitional and merely looks at the past as a way to conceptualise the future. Such thinking may constrain opportunities in the new networked world (Lyman 1996).

In other words, there is a danger that certain features of existing libraries are being unreflectively conserved, as are certain features of an idealised and unreal past. The future lies in developing new understandings between librarians, technologists and users

> To participate most fully, librarians will need the help of technologists to better understand the possibilities being created by digital technologies, and technologists will need the help of librarians to appreciate the richness of traditional librarianship and to identify aspects of it that are most relevant to the continuing evolution of libraries (Levy & Marshall 1995).

Understanding digital libraries: a conceptual framework

Some library models

> Exactly what a digital library is and how it is to be organised have not yet been determined (Braude et al. 1995)

We can distinguish three general models for the development of digital libraries. In general terms, these correspond to the digital library, the hybrid library and the electronic library. The relative meaning of these terms is discussed in a previous paper – Bawden & Rowlands 1999a.

The simplest, and the least likely to be a model for any current or future library service, is the electronic library model. This envisages the library as a physical place, in which users may access digital resources one at a time. These electronic resources are selected, acquired, and made available for access and searching in very much the same way as traditional resources. This is a model of an incremental progress from traditional to digital, but is very much an automation of the *status quo.* It is unlikely that any library service would aspire to operate on such a model, and it may be regarded as a warning of the wrong way to digitise. As Rusbridge points out, however, absurd though it may be, it is the only model that can maintain anything like the traditional relationship with publishers, and the economic implications of this.

The hybrid library (Pinfield et al. 1998, Brophy & Fisher 1998, Oppenheim & Smithson 1999) is generally viewed by its proponents as a model in its own right, to be developed and improved, though it may be viewed by others as a transitional stage towards a truly digital library. This model represents the typical 'real world' situation, with pragmatic access to information from a range of media and formats, within an ideal of ever-closer integration and interoperability:

> it follows that most users will continue to be offered a mix of formats via a mix of delivery systems. The challenge for library managers is to create integrated services which provide a 'seamless' service to the user. (Brophy & Fisher 1998)

The hybrid library, since it has an element of physical provision, and by implication a physical location in which these are stored and accessed,
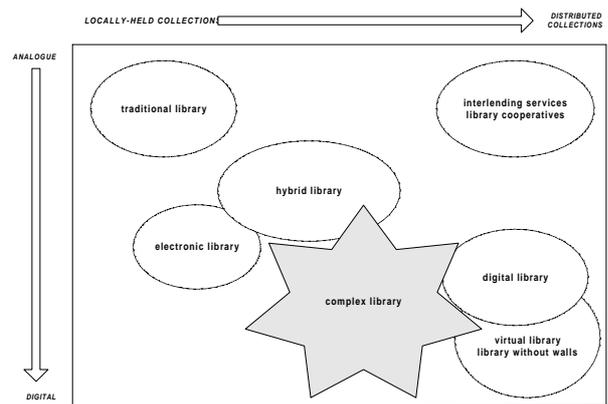
Figure 2: Locating the digital library concept

seems almost invariably to be an institutional model. In this way, it preserves the general concept of the traditional library, and, almost incidentally, retains the notation of the library as place; although there is considerable debate in the literature as to whether such an entity is properly regarded as primarily a place or a distributed process. Be that as it may, it seems clear that there will be a physical location associated with a hybrid (or gateway) library. The value of this should not be under-estimated, whether as the provision of space for student study in an educational institution, for community activities in a public library, or for knowledge management in a commercial organisation, for which the physical conditions for knowledge sharing are being increasingly recognised as important. The hybrid library, for the same reasons, has an extended temporal existence. Figure 2 summarises the relationship between traditional, electronic, hybrid and digital libraries in a two-dimensional space, which emphasises relative degrees of distributed access and digital content.

The digital library proper may be based on an institution, but equally it could be based on a subject discipline, a vocation or profession, a region or even a nation. While such an entity may have a physical location, it need not. It may be called into existence very rapidly, and dispersed equally rapidly; indeed it has been suggested that such 'limited life' digital libraries could be a created as a response to, for example, medical or environmental emergencies. The true digital library also has within it the capability to disrupt and reconstruct the publishing and knowledge

creation system. This being the case, providing realistic models for this type of library is much more difficult that for the previous two, purely on account of its dynamic, multifaceted and multi-choice nature. One approach, which seems to encompass much thought in this area, suggests that a model of the digital library should comprise four structural levels:

- user interface;

- networks and communications;

- information resources;

- reference service system

supporting five basic kinds of functionality:

- digitisation;

- large repositories;

- fast data transfer;

- privilege;

- management (Yang and others 1997).

Models of the digital library *per se* are, however, inadequate, if they do not allow modelling of the change in the nature of publication due to digitisation; traditional library models, assuming 'traditional' acquisition inputs, are necessarily inadequate. An example of this is a hybrid publishing model, with greater interconnection of print and web publications and further development of value-added services on the Web version (MacColl 1997).

Three separate general models are suggested above, corresponding to what we have termed the electronic, hybrid and digital library respectively. These may be combined into one overall general model, using Crawford's (1999) concept of the complex library, discussed in a previous paper (Bawden & Rowlands 1999a).

We consider that Crawford's concept of the complex library is a useful one, to cover all those systems and services having a degree of digitisation. For one thing, it is eminently descriptive of the complicated situations with which librarians (and researchers) must cope. It avoids the negative connotations of 'hybrid', with its suggestion of an awkward transitional phase; Collier (1997) also criticises the 'hybrid' metaphor, since it 'simply expresses the obvious'. It is also possible, and helpful, to use an analogy with the mathematical
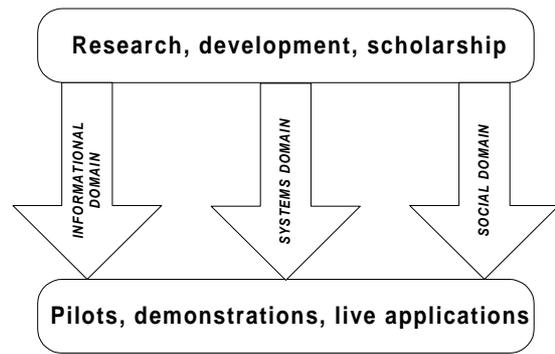

Figure 3: Digital library research: theory and practice

concept of complex number, by which all numbers are thought of as including a real part and an imaginary part. By analogy we may think of a complex library as comprising both real and virtual components. A traditional library, a physical place with a collection of physical information items, would have a real component, but no virtual component. A hybrid library would include both components, in varying degree. A truly digital library would be entirely virtual, with no real (physical) components whatever. It is interesting to speculate whether such a thing could exist; in its full sense it would, of course, have to have no staff, and be serviced by virtual agents. Perhaps the closest approach to it that could currently be envisaged in practice is a collection of digital resources, brought together for a particular need, without any institutional focus, nor any staff dedicated to it.

Theory and practice

Digital library literature includes examples both of original academic research and opinion papers by library practitioners. The relationship between research (the world of ideas) and the real world of pilot and demonstration projects and digital library innovation is represented below. In fact, reality is more fluid and dynamic than Figure 3 suggests; ideas flow up as well as down, and sometimes cross over from one domain to another.

The fluidity of the transfer of technology between research, development and practice in the fast-moving world of the evolving digital library is a topic itself worthy of further attention.
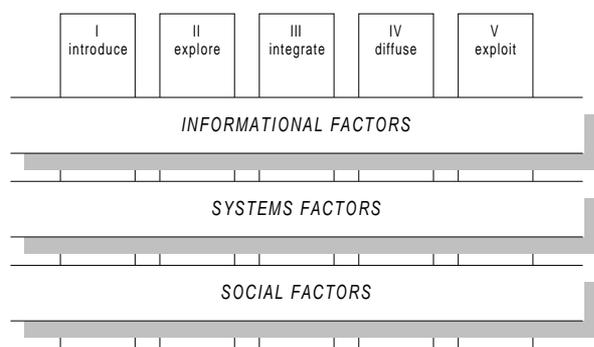
Figure 4: The digital library life cycle

Figure 5: Feedback mechanisms in the evolution of digital libraries

Evaluating the digital library

In this section we look at two models which may help to clarify some of these questions. Figure 4 is adapted freely from the work of Edna Reid (1999), who has clearly been deeply influenced in turn by Michael Scott-Morton's pioneering book *The Corporation of the 1990s* (1991). Reid's is a five-level model, which might be used to classify digital library pilots and initiatives based on the stage reached at a particular point in time as they roll out in the organisation.

Digital library demonstrations and pilots are first introduced (I), then explored more fully in the work setting (II), gradually integrated with other services such as document delivery (III), then more widely diffused both within and across organisations (IV), and finally exploited to secure some kind of business advantage (V).

This process of rollout and exploitation naturally involves solving and ameliorating problems as they arise in the informational, systems and social domains. For example, the diffusion of a digital library application across different departments of the same organisation may involve publishing local databases in a standard form (the informational domain), solving problems raised by legacy hardware and software (the systems domain) and encouraging staff to change long-standing patterns of work practice (the social domain).

Barry (1997) identifies five key issues in the evaluation of digital library initiatives:

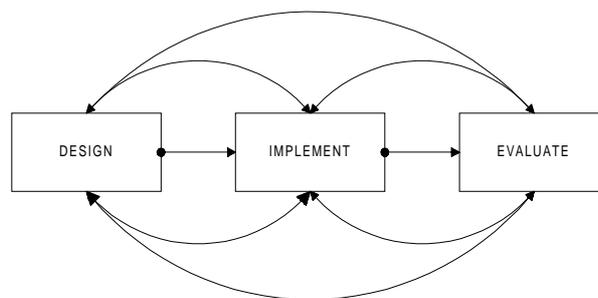- incomplete knowledge of the operating variables in this new area;

- the complexity of the information search process;

- the implicit nature of information and research skills;

- the difficulty of measuring outcomes, say in research terms;

- incomplete knowledge of the role information systems and services play in supporting research.

Figure 5 further stresses the temporal aspects of digital library developments and, especially, the need for evaluation, reflection and analysis. Feedback loops, between design, implementation and evaluation (involving users) and between the world of ideas and the world of practice need to be better understood, and facilitated where necessary.

This is a far from trivial problem. Digital library pilot and demonstration projects differ enormously in their assumptions, terms of reference, degree of component autonomy, task complexity and scale. Comparing outcomes is enormously difficult, especially in the face of developments that by their very nature draw on concepts of heterogeneity, federation and interoperability. The lack of robust and commonly agreed criteria for evaluating various aspects of the performance in the digital library is a cause for concern and represents an area where more research is urgently needed.

The conceptual framework

Finally, we synthesise some of the main points presented so far in the form of our conceptual framework (Figure 6). This relates the worlds of ideas and practice to a dynamic conception of the digital library with a strong temporal aspect (left-
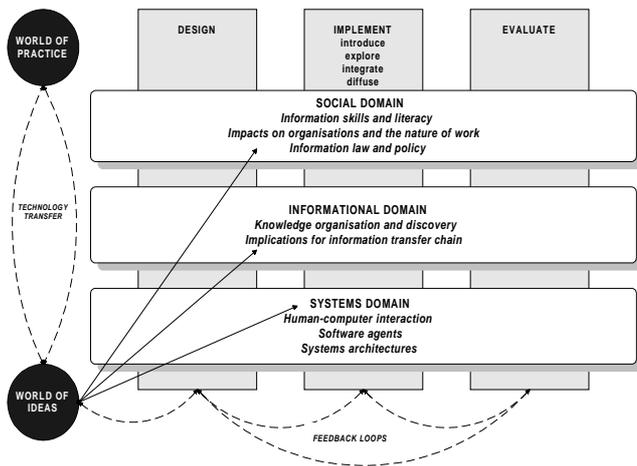
Figure 6: Understanding digital libraries

right) and informed by ideas rooted in Yates' notion of documents, technologies and work.

We believe this framework summarises many important issues in digital library research, not least the need for greater reflection and evaluation, a more *transdisciplinary* approach, and closer co-operation between academic, practitioner, user and policy-making communities. It should provide a valuable tool for understanding the nature of digital libraries and for comparing and analysis the results of research and the experience of practice.

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Notes

1. The review covered the period 1995 to the present and was based on materials indexed in the following online files: Science Citation Index, Social Sciences Citation Index, Library & Information Abstracts, Information Science Abstracts, Educational Resources Information Centre, Dissertation Abstracts and Applied Social Sciences Abstracts. Additional research was carried out on the World Wide Web using AltaVista. Some earlier materials are included where appropriate.

were introduced: the first was the replacement of writing on scrolls with sep-arate pages which could be gathered into books, and later—the numbering of the pages. It enabled scholars to move away from the relatively-linear data searches in traditional digital libraries and databases, to knowledge construction from information that was access-ed in a nonlinear manner. Until the early 1990s, work in the restricted com-puter environments, most of which were not based on the hypermedia tech-nology, promoted relatively linear thinking. JULY 2005. Number 3. A conceptual framework for digital libraries for K–12 mathematics education: part 1, information organiza-tion, information literacy, and integrated LEARNING1. Hsin-liang Chen2 and Philip Doty3. This article is the rst of two that present a six-part conceptual framework for the design and evaluation of digital libraries meant to support mathematics education in K–12 settings (see also pt. 2). This rst article concentrates on (1) information organization, (2) information literacy, and (3) integrated learning with multimedia materials.