Design and Evaluation of a Task-based Digital Library for the Academic Community

N. Meyyappan¹, Schubert Foo¹ and G.G. Chowdhury²

¹Division of Information Studies, School of Communication and Information
Nanyang Technological University, Singapore

²Graduate School of Informatics, Department of Computer and Information Sciences
University of Strathclyde, Glasgow, UK

Abstract

The paper discusses the design, development and evaluation of a task-based digital library, Digital Work Environment (DWE), for the academic community of higher education institutions (HEI) with Nanyang Technological University, Singapore, as a case. Three different information organisation approaches, namely, alphabetical, subject category and task-based approach were used to organise the wide range of heterogeneous information resources that were interfaced to DWE. A user evaluation study using a series of task scenarios was carried out to gauge the effectiveness and usefulness of DWE and these information organisation approaches. The time taken by respondents to identify and access the relevant information resources for individual tasks was also measured. The findings show that the task-based approach took the least time in identifying information resources. Regression analysis on information resources location time with gender, age, computer experience and digital resources experience of the participants are also reported.

1 Introduction

Many questions still remain unanswered in digital library (DL) research, especially in the areas of collection management, information organization, and information retrieval. Information resources are organized in many different ways in different digital libraries. From the users’ point of view, they would like to get access to information in digital libraries with minimal cost, time and effort. Such factors are important design and evaluation parameters to determine the effectiveness and efficiency of the library to meet user needs. This paper traces the design and development of the user-centered digital library for higher education institutions (HEIs). We propose an interface system that would act as a one-stop window for users to get access to all kinds of digital information sources and services – be it available through the library, university and departmental intranets, or the Internet. We call this a Digital Work Environment (DWE). The Division of Information Studies (DIS) at Nanyang Technological University, Singapore, was chosen as a case to build a prototype for this research. Details of the design and architecture of DWE has appeared elsewhere (Meyyappan, Chowdhury and Foo, 2000b; 2001). However, we have provided a brief overview of DWE later in this paper in order to facilitate our discussions on its evaluation.
Three different approaches to information organisation are supported by DWE, namely, the task-based approach, alphabetical list approach and subject-based approach. This paper reports the main findings of the user evaluation studies carried out on DWE to gauge the usefulness and effectiveness of these different approaches to information organisation. In particular, it aims to compare how the proposed task-based approach performs against other approaches in terms of ease of use, time taken to locate the needed information resources, and user effort through the number of mouse clicks required to complete a set of prescribed information seeking tasks.

2 Review of Related Works

The spread of interest in DL has not only ensured rapid growth of the field, but also introduced differing contexts, approaches, emphases, practices and views. A number of publications reporting on the completed and on-going digital library projects are now available (see for example, DL12, 2003; Fox, 1999; eLib, 2001; ERCIM, n.d.; Fox and Urs, 2002). The rapid growth of DLs, together with the professional publications and the popular press, have created a lot of hope as well as myths about digital libraries.

2.1 Problems of DL Users in HEIs

The academic community is possibly the largest and the most important user group of digital libraries. User requirements from a digital library are influenced by their nature of work, affiliation, educational background, accessibility to technology, and so on. Apart from the various information resources that are currently managed, provided and accessed by digital libraries, there is a variety of other information that is needed by users in an academic community. However, currently such information is either not available at all or is partially available to only a certain section of the user community. A review of twenty working digital libraries from different parts of the world-representing academic, special and public libraries revealed the diversified collection of information resources (Meyyappan, Chowdhury and Foo, 2000a). The various information resources accessible to users include full-text journal articles, proceedings papers, technical reports, theses and dissertations, patents, e-journals, e-books, examination papers, photographs, images of historic buildings, maps, audio, video, multimedia databases, collections of manuscripts, sound recordings, music collections, OPACs, Union Catalogues, CD-ROM databases, online databases, local publication databases, locally produced theses and dissertations, etc. However, information resources such as course calendars, university statutes, various course handbooks, course registration information, thesis and dissertation guidelines, style guides, laboratory facilities, availability of software, hardware and laboratory equipments, course materials, handouts, etc., are not usually managed by DLs, though they are quite frequently required and used by the academic community. These resources are available at different locations, on different servers in different formats and with different access means and restrictions. Some of these resources are available in academic (institutional or departmental) Intranets. Currently, digital libraries do not manage or provide access to these diverse but yet extremely useful collections of information.

As such, the problems faced by users of an academic digital library are many. First of all, they do not know which information source may be appropriate to accomplish a particular task or to resolve a particular problem. Secondly, even if users are aware of the existence of a particular information source, they may not know where and how to locate it, and finally how to retrieve the information. Current online information services, including digital libraries and the Web, expect users to know what they want and also expect them to formulate a query to represent their information needs, or to map their query onto the knowledge structure (subject directory) that is often not quite easy. Moreover, users’ information needs usually arise as the result of the need to complete specific tasks. Current digital information systems, such as those obtained from digital libraries or the Web, are not organised to match the various tasks that users perform. As a result, users often source for information through trial and error, and browse Web pages...
from one to another, or move from one information resource to another to obtain the desired information. This is unproductive and results in a waste of time and energy. Some recent research efforts have been directed to build personalised digital library environments to solve some of these problems (see for example, Adams, Judith and Sharon, 1995; Zhang, 1998; Zhao, 1998; Barry and Barbara, 1999; and Suzane, et al, 2000). Some studies on the user-centred digital library design have also been in the literature (see for example, Amato and Straccia, 1999; Mann Library, 2003; Theng et al, 1999). However, none of these research projects has proposed a one-stop approach to providing access to all kinds of electronic information, available through the digital/hybrid as well as intranets, required by the user in an academic community.

2.2 User needs

Assessment of user requirements is a usual exercise undertaken by Library and Information Science (LIS) researchers and this has not changed in the digital environment (Collier, 1996). However the volume of user studies on digital environment is less than the traditional user studies. In a study reported in the pre-DL era, Garvey, et al. (1979) noted that the success of information services was more likely to be achieved through adjusting the services to meet the specific needs of an individual rather than trying to adapt the individual user to match the wholesale output of an information system. Mick et al. (1980) recognised that the effective transition into the information age would require switching from information systems that are technology and content driven to information systems that are user-driven.

There is an increasing evidence to show that some DL design had heeded these calls and attempted to create more user-centred designs (see for example, House et al, 1996a, 1996b; Theng et al , 1999; Borgman, 2000; Hill et al, 1997; Dillon and Song, 1998; and Choudhury et al, 2002). Many such studies have focused on understanding the users, their context and their work; advise on content, functionality and interface design; and provided feedback on designs and prototypes by means of heuristic evaluation, small-scale user feedback and large-scale user testing (House et al., 1996a; 1996b).

2.3 Personalised Digital Libraries

Projects such as MyLibrary (2002) of the Cornell University Library initiative, MyLibrary@NCState (2001) have focused on personal DL collections and services. These studies have facilitated the creation of a dynamic and customised gateway to both general and discipline specific resources. These implementations address users’ information needs via a limited set of five or six groups of information - personal links, bibliographic databases, electronic journals, etc. Many do not have enough flexibility to allow their users to customise it to their own needs. A wider option for supporting customization such as using portal-type technology to present an information environment that is personalized to the users’ needs, and support user customization is preferred. An example of such an environment is Hybrid Electronic Access and Delivery in the Library Networked Environment (HeadLine, 2001). This three-year project, developed as a hybrid library system known as the HeadLine Personal Information Environment (PIE), designed and implemented a working model of the hybrid library, in actual academic environments in the subject areas of Economics and Business Studies. The project presents the user with a wide range of library resources, regardless of physical form, via a common Web-based interface. The PIE uses portal-type technology to present an information environment that is personalized to the users’ needs and support users’ customization.

2.4 Task-Oriented Research in Digital Libraries

Current digital libraries and the Web environment are mainly designed based on a systems approach. Less or little emphasis has been put on the users in such settings. Users are expected to be able to address the ‘what’, ‘where’, ‘when’ and ‘how’ questions in their quest to seek information. Although users’
information needs are often related to some form of their immediate task in one way or another, current
digital libraries or information systems do not generally organize information according to the various
user tasks. The user-centred approach to digital library design is therefore desirable as it aims to shift the
focus from a system-oriented to a user-oriented design in an attempt to meet users’ real needs and
facilitating means and ways to support their information seeking and use behavior according to their
tasks. Building a system using a task-based design provides an appropriate means and solution to
organize and group these resources according to the tasks needed to accomplish different types of jobs.
The proposed system has the potential to resolve the user’s problem by offering a user-friendly
environment that serves to aid the user to locate, access and use information directly, and to meet their
information needs according to tasks.

Task-based design and analysis is accepted within the Human Computer Interface (HCI) community as an
important tool in designing interactive applications. It has been recognized as an important factor in user
interface design (Gould and Lewis, 1985; Lewis and Rieman, 1993; Cousins, 1996). While task-based
design forms the basis for software and system development, it is only recently, that we have seen models
that offer a tighter integration of task analysis activities with subsequent design activities, thereby
supporting greater use of task information in creating user interface designs. Task-based user interface
design emphasises the importance of users and their tasks at the starting point of the design process itself.
It emphasises the importance of designers developing an understanding of users' existing work tasks, the
requirements of changing those tasks, and the consequences that new designs may have on tasks (Wilson
and Johnson, 1996). Thus, ‘the tasks, the user has to fulfill with a system to be developed should play an
important role in its design’ (Birgit and Szwillus, 1998).

3 Digital Work Environment (DWE)

In addition to the findings of the studies mentioned above, we conducted a small-scale study to assess the
general users’ views on information access in digital libraries. The participants selected for this study
were students from the Division of Information Studies (DIS), Nanyang Technological University (NTU),
Singapore. They were graduate students of the Master of Science in Information Studies programme and
came from different backgrounds. The assistance of one faculty and one library professional was also
invoked to provide further suggestions and recommendations on the types of information resources that
are used by students to meet their information needs.

A total of fifty-seven Masters’ students, one Associate Professor and one library professional took part in
the study. Prior to the study, a discussion guide with brief information about the objective and usefulness
on the study was given to all participants. In the first part of the session, three digital libraries were
demonstrated to participants. They included the American Memory (AMMEM) (American Memory,
2003), GEMS (Gateway Electronic Media Services, currently called iGEMS (iGEMS, 2002)) of the
Nanyang Technological University and HeadLine (2001). They represent a general DL, local DL and a
specific DL for the academic community. The demonstration mainly focused on the collection,
organization and interface aspects of the digital libraries. After the demonstration, participants were given
60 minutes to use these digital libraries to explore and familiarize themselves with them. They were
asked to pay special attention to features such as information organization, collection coverage, typical
forms of information resources interface and search capability. Inputs from the session and the
discussions were noted by the researcher and tape-recorded.

In interacting with AMMEM, participants expressed problems in identifying needed information
resources for their information requirements and general information search. While interacting with
GEMS, the participants suggested the incorporation of an additional layer on top of GEMS to direct users
to its vast array of resources that are interfaced to different servers, Internet and Intranet via tasks. It
should be noted that GEMS is not a task-oriented DL. Participants desired that required information
resources available in different servers had to be filtered to meet their requirements according to various categories of users and their tasks. Participants also expressed the requirements for some special features to record frequently needed information resources for their use, searching heterogeneous information resources, full-text search capability, metadata about information resources, resources sorting facility and customization feature to allow them to create personal folders according to their nature of their work. Basically, participants advocated for the need for a customized DL with information resources search, sort and other facilities according to their tasks.

As a solution to the problems discussed above, we proposed to design an information organization and access system, known as DWE (Digital Work Environment), that would:

1. provide a one-stop information access point for both internal and external information that are accessed by the various constituents (such as Faculty, Student and Others) of the academic community. This includes access to information resources in the in-house academic libraries, local and remote digital libraries, and the vast array of information resources in the academic institution’s own Intranet systems;
2. be task-based to allow the user to choose a task (from a list of tasks usually performed by him/her), and the system would then automatically lead the user to the relevant information resources;
3. provide alternative modes of access to information, for example through browsing or through a cross-database search; and
4. allow the users build a personal work space for storing links to useful information resources for future reference.

The basic tenet is that the users need not know about the existence (or non-existence) of a particular information source nor do they need to formulate a query to look for an information source. The proposed DWE expects a user to identify a particular task that he/she wants to accomplish at a particular moment, and the system, based on its knowledge about the given users as well as of the various information resources and their suitability to a particular task, will take the user to the appropriate source of information.

Within the DWE prototype and its basic task-based support, we also organized information resources using different approaches (discussed in Section 3.8) since our intention was to assess whether a task-based information organization is indeed any better than the conventional alphabetical or classified approaches to the organization of information resources.

3.1 DWE Prototype Development

The DWE prototype was developed in the Division of Information Studies (DIS), School of Computer Engineering (SCE) at Nanyang Technological University (NTU). This section reports on a number of issues that were addressed in the DWE prototype development.

3.1.1 Identification of Various User Categories and Their Tasks

DWE users are organized into 3 main categories of Faculty, Student and Others (Nanyang Technological university, 2000a; 2000b). The information needs of each category of users vary according to their nature of work. It also varies from school to school and division to division in the academic environment. An analysis of various categories of users and their tasks was discussed in detail in our earlier publications (Meyyappan, Chowdhury and Foo, 2000b, 2001; Meyyappan, Hawamdeh and Foo, 2001).
3.1.2 Identification of Information Resources
The NTU library is a major information resource centre for the NTU academic community (Nanyang Technological University Library, 2002). The NTU library has a good collection of reference materials, reserve book collection, course materials, CD-ROM databases and e-journals. Based on the analysis of various user categories, their tasks information resources architecture has been designed.

3.2 Basic Architecture of the System

Figure 1 shows the basic architecture of the DWE. The system consists of a User Interface (UI) module that is linked to the Task Maintenance, Resource Maintenance, Information Resource organisation, Statistics and User Authentication & Management modules for carrying out the various functions of DWE. Details of the various components of DWE and their functions have been discussed in earlier papers (Meyyappan, Chowdhury and Foo, 2000b, 2001).

![Figure 1. Architecture of DWE](image)

3.3 Users

The environment is used by three main groups of users, namely, the Information Resource Administrator, User Manager and the general academic users.

The **Information Resource Administrator** is responsible for collecting information about various categories of users, various tasks that are accomplished by each category of users of the digital library community DWE serves and information resources that are required to accomplish these tasks (such as databases, Intranet resource, folders, library and Internet resources), as well as the necessary URLs, update of databases and access information to these various resources.
The **User Manager** manages the collection of user-related information, creation of user accounts, maintenance of the user database and users personal space data in the personal database.

The **Users** of DWE include all types of users of the academic community. They interact with DWE to obtain information to accomplish particular tasks that are specific to their vocation. Thus, specific user groups with different user needs must be identified, along with their typical tasks and information resources in order to allow DWE to fulfill its role of being a one-stop centre for information to meet the varying information needs of these users.

### 3.4 Information Resources

The environment relies heavily on the information resources that are interfaced to the system to provide the input information to meet users needs. These resources are available in different forms and formats and are placed at different locations such as traditional libraries, digital libraries, web pages, CD-ROM and online databases and MS exchange folders, etc. Within NTU, information resources, other than library resources, such as databases, folders, web pages, and so on, are scattered in different Schools, Research Centres, Centre for IT Systems (CITS), Registrar’s and other Administrative Offices of the university. Each School maintains and hosts its own website. There are a wide variety of information resources in an academic environment such as course information, course materials, academic calendar, in-house training, student exchange programme, various courses, laboratory schedules, course materials, in-house training facilities, alumni association, club activities, and so on. These information resources are provided to users according to their tasks through DWE.

### 3.5 Main Modules of the DWE

To meet user needs in an efficient and effective way, DWE was designed using five modules comprising the Information resources organiser module, task module, resource maintenance module, statistical module, user authentication and management module.

**Information Resources Organiser Module** This module responses to the users request through the user interface and interacts with servers in the Intranet, library home page, databases, folders and Internet resources, to retrieve the needed information resources to users. Some information resources such as e-journals and CD-ROM databases need authorisation before usage. DWE manages this aspect of access so that the user does not need to worry about access authorisation codes, user-ids and passwords for different resources, instead, this module facilitates access through a single DWE password. As such, the module is used for the management of all the information resources that are interfaced to DWE.

**Task Maintenance Module** The tasks of different user groups vary according to their nature of work. This module links the various categories of users with their tasks. It is used by the Information Resource Administrator to update the respective tasks, sub-tasks of various categories of users in the database.

**Resource Maintenance Module** This module links information resources for all tasks and sub-tasks through a hierarchical structure. Through this module, resource links for user tasks and metadata information are managed. The aim is to provide a convenient means to update such information when the need arises. One information resource may be linked to many categories of user’s task or one task may have a number of information resources. This module will also check and ensure the referential integrity of data in the databases prior to any updates.

**Statistics Module** This module keeps a log of the operational statistics of DWE for the administration and management of the system. Examples of statistics that can be obtained include the number of users
using the system during any defined period, identification of frequent or inactive users, frequently used
information resources, when individual information resources was last accessed, and so on.

**User Authentication and Management Module**  This module identifies a user and the specific user
group during the login process and interacts with user category database for displaying tasks related to
that category of user. The module is used by the User Manager to manage all DWE users and their
personal databases (personal folders, personal spaces and favourite links).

### 3.6 Prototype DWE

In order to derive the task-based design of DWE, a task analysis was needed to identify the different types
of tasks and sub-tasks that are carried out by the different groups of academic users. Using the Master’s
dissertation as a representative task, a job analysis was first carried out to identify all the main tasks
associated with the dissertation process. Each main task was sub-divided logically into sub-tasks and
sub-sub-tasks thereby creating a task hierarchy for the dissertation task. Hierarchical task analysis was
adopted. Different resources and information that are required at these varying levels in the task hierarchy
were identified. On the basis of this, a first-cut DWE prototype was developed. A focus group study was
subsequently conducted to demonstrate the first version of the prototype and to further elicit user needs
and feedback. All the 10-faculty members of DIS and three research students took part in the study.
Further improvements were made to this initial prototype as the result of this focus group that was
conducted to elicit feedback of the prototype.

### 3.7 Implementation of DWE

All users (Resource Administrator, User Manager and Users) interact with the DWE through a unified
web interface via a URL. This section briefly describes the main issues in the implementation of DWE,
namely, technical infrastructure and user interface.

#### 3.7.1 Technical Infrastructure

DWE is essentially a database application, accessible from an HTTP and HTML interface, and governed
by the principles and practices of librarianship. DWE is built on four computer software technologies: an
operating system, HTTP server (Java Web Server), a structured query language (SQL) database server
and a scripting language using JavaScript/Java Servlet.

DWE resides and runs on the Windows NT Server, which has its own security features. DWE uses the
Java Web Server (JWS) 2.0 as its HTTP server. Java Servlets written to the Java Servlet API can work
with those servers as well. This facilitates to extend server functionality in a uniform way without having
to worry about the particular server software or platform being used. JWS 2.0 itself has the familiar
benefits of platform independence as any Java application. Using this architecture, presenting, entering,
and updating data is handled by the front-end using Java Servlets and JavaScript in the DWE.

The identified user categories, user tasks, and the information resources are organised in a suitable form
for easy and effective retrieval. The MS Access relational database management software was chosen
primarily due to its ease of use, including its support for Open Database Connectivity (ODBC) and
application programmer's interface (API) for Java. This database serves its purpose well for the
prototype, but can be replaced with a more robust database in future.
3.7.2 DWE User Interface

DWE uses a frame-based interface as shown in Figure 2. Three frames are used in the interface design. The *Welcome* frame contains welcome information, help and access to the different resource view options and sort facility for displaying information resource.

The *Navigation* frame makes use of a hierarchical tree structure, similar to the widely adopted Windows Explorer model, to show the various task and sub-tasks, starting with the general task and ending with the specific lowest level of sub-task. Different tree structures are presented to users upon successful logins based on their user category.

![Figure 2. DWE Main Page](image)

Upon selecting an appropriate sub-task (leaf in the hierarchical tree), the corresponding information resources are shown in the *Display* frame. Users have different options to display these resources in the *Display* frame: by alphabetical order, by LCSH subject headings, by resource-type, date of last access or frequency of use. Different icons are used to indicate different information resource and for denoting the current status of the information resources.

### 3.8 Different Approaches to Information Resource Organisation

As mentioned at the beginning of Section 3, we intended to assess whether the task-based approach was any better than the conventional alphabetical and classified approaches to information organization. For this, the task-based (TB) model (shown in Figure 3) was augmented with two additional information organisation approaches, namely, the alphabetical resource approach (AR) and the subject category
The alphabetical resources (AR) approach basically lists all the DL’s interfaced information resources in alphanumeric order (Figure 4). This approach is simple and intuitive. Users simply scroll down the list to identify the needed information resource. The information displayed includes the information resources title, resource format, resource form, number of times the resource was accessed and the last date of access.

The subject category (SC) approach organises the information resources according to different subject categories based on the Library of Congress Subject Headings (LCSH) (Figure 5). Users navigate through the links to identify the appropriate subject area and accompanying information resources. The number alongside each subject heading shown within the brackets in Figure 3 indicates the number of information resources listed under the subject heading. When no suitable LCSH headings were available, the ASIS Library and Information Sciences thesaurus was used as the controlled vocabulary to describe the subject categories.

The total number of information resources that are interfaced to the three approaches is the same. The only difference is the way they are organised and accessed by the user. In TB, users will traverse to the appropriate level of task or sub-task hierarchies where they will be presented with a list of required information resources that are needed to accomplish the chosen task. Upon selecting the desired information resource, DWE will automatically display the resource in the display panel for display as shown in Figure 6.

In the TB approach, users are first authenticated during the logging in process. The system will determine the user group and accordingly present them with a customised interface of tasks for their selection. Using the navigational links, users will traverse to the appropriate level of task or sub-task hierarchy where they will be presented with a list of required information resources that are needed to accomplish the chosen task. As such, the TB approach effectively filters away all unwanted information from the vast amounts of information resources that are interfaced to the digital library and only present the necessary and essential information resources.
<table>
<thead>
<tr>
<th>Title</th>
<th>Subtitle</th>
<th>Type</th>
<th>Format</th>
<th>Last Access</th>
<th>Author</th>
<th>Form</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>Acronym Definition</td>
<td>Text</td>
<td>HTML</td>
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<td>6</td>
<td></td>
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</tr>
<tr>
<td>Acronym</td>
<td>Relations to the System</td>
<td>Text</td>
<td>HTML</td>
<td>2010-09-01</td>
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<td>Acronym</td>
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</tbody>
</table>

**Figure 3.** Task-based Approach

**Figure 4.** Alphabetical Approach
In the hybrid approach (HY), users have the choice to select one of the three earlier methods to gain access to the information resources (Figure 7). DWE also supports a generic search facility to support those users who would prefer to conduct searches themselves.
3.9 Search Features

In addition to locating and using resources through the different approaches, DWE also supports a number of different search strategies. Users can directly search for documents on specific types of resources (e.g. CD-ROM/online databases, e-journals, GEMS OPAC, the university Intranet, Internet), multiple systems or services (e.g. NTU Library OPAC or GEMS), or use a single federated search to search for all possible information resources that are interfaced to DWE. Depending on the search option selected, different search features are supported. This includes simple keyword search, phrase search, Boolean search and truncation operator. Users can also search using task or sub-tasks information so that DWE will return all information resources matching the task query (Figure 8).
In terms of the combined search, DWE supports both keyword and author query as shown in Figure 9. The query is subsequently translated into a series of appropriate formats and directed to the different chosen search systems.

In terms of Internet, DWE acts as a meta-search engine by sending the processed query to individual search engines. However, the results returned by the search engines are not further processed; instead, they are simply shown to the user on separate cascading windows according to the display format of the systems.
3.10 Additional DWE Features

DWE also incorporates a personal space and folder for users to store and access various information resources at a later point in time. The personal space is used to record users’ favorite or frequently used URLs. This is basically a convenient bookmark facility for users to revisit stored URLs, or to update or add new URLs over time. Links to full-text paper is stored under this option. Users can also make notes on important quotes, texts or other annotations and store them in the personal space. This information is also indexed using a full-text information retrieval software called dTSearch and integrated in DWE to support subsequent query and retrieval.

In addition, DWE allows users to create their personal folders to store and manage their own information space (Figure 10). Any number of information resources can be copied or moved into each folder as necessary.

In terms of statistics, DWE keeps a record of a number of different statistics to aid the overall management of the system. These basically include individual login information, information resource access and usage statistics, and task statistics. From these, it becomes possible for the Administrator to identify user activity during different periods, individual user logs, frequency of use of information resources, latest accessed resources, frequently used tasks and sub-tasks, active and inactive users and information resources in the system. Finally, DWE also houses an administrative module to aid the maintenance and management process. This is accessed through an administration interface containing a series of hyper links to support creating, modifying or deleting content in the various DWE databases.

4 DL Evaluation

In a DL environment, one major difficulty faced by users is the navigation of large document spaces, as they often experience a disorientation problem such as remembering the location in the network, make decisions about where to go next, and keep track of pages previously visited. To address this problem,
Heflin, et al (2001) developed a tool, WebTOC that automatically creates a hierarchical structure of the contents of a website and presents it in the form of a table of contents, and conducted an evaluation study.

In a digital environment, it is necessary to find new, reliable indicators of service provided. Use of electronic services may be measured by reference to connect time, number of sessions, number of concurrent sessions, number of hits, number of active users and various other factors. A working group on Digital Library Metrics is currently developing a consensus on an appropriate set of metrics to evaluate and compare the effectiveness of digital libraries and component technologies in a distributed environment (D-Lib Working Group, 2001). The Digital Library Evaluation Forum of the DELOS Network of Excellence is developing an infrastructure for the evaluation of digital libraries particularly performance related aspects in access. Fuhr, et al (2001) developed a new description scheme using the major criteria of collection, technology, users and usage.

4.1 Evaluation of DWE

The task-based approach adopted in DWE aims to provide navigation through a hierarchical organisation of tasks and sub-tasks that are typically carried out in the digital library environment, with the idea of providing a one-stop point for accessing relevant information resources by filtering out unwanted information resources automatically to match the various user profiles.

DWE also aims to offer other forms of value-added services to users like personal folders, personal workspace, and to ensure access control, authentication, and the provision of user and usage statistics that are helpful for management as well as planning. In essence, the ultimate objective of the DWE design is to allow the users interact with the interface and support the provision of information resources suitable for accomplishing a chosen task, and thereby reducing search time with minimum user-efforts. This is a new approach to organizing information in digital libraries, which could be used as a stand-alone tool, or used in combination with the other more established approaches of the alphabetical, subject based and hybrid approach. However, once the prototype DWE was designed, we wanted to investigate the following questions:

1. What are the alternative techniques in organising and presenting online distributed resources from different systems and services in an academic community in order to fulfill the information needs of its various groups of users?

2. Which are the most effective forms of information organisation techniques for DWE when assessed along the parameters of speed of access, and ease of use and access in accomplishing a set of typical digital library tasks?

3. What is the overall effectiveness of DWE, specifically the proposed Web-based value-added unified interface, in providing access to different information resources?

4.2 DWE Evaluation Tasks

In order to answer the above questions, an evaluation of DWE was conducted that involved a combination of techniques, in the form of close and open-ended questionnaires, and measurement, in the form of rating and ranking scales, and qualitative feedback. In order to carry out the evaluation, ten representative tasks for users undergoing the dissertation process were identified. Each task was associated with some form of information seeking job and would vary due to the nature of the task. These included (1) finding faculty members working in specific research areas, (2) finding specific documents in the DWE, (3) finding specific journal information, (4) finding the author of an article, (5) finding an article in a
specialised area, (6) finding citation of an article, (7) identifying various techniques associated with a particular research methodology, (8) identifying information from the Internet, (9) identifying a number of information resources on a particular area, and (10) retrieving documents through OPACs.

In the evaluation, two sets each of 10 evaluation tasks were compiled. The data collection was done on a one-to-one basis under a controlled environment. The researcher first explained the basics, aims, objectives and features of the DWE and demonstrated the system to the participants. The participants were given 10 minutes to use and familiarize with the system. The series of tasks was subsequently presented to the participants for completion. For every task, the participant completed and answered the questions in the evaluation form before moving on to the next task. The researcher sat alongside each participant and timed the process for each task. This time to read the task instructions (TU), time to select a particular approach ((TS) - only for HY), time to locate the information resource (TL), time to identify the required information in the information resource (TI), and time for recording the answer (TR). Thus time taken to complete a single evaluation task, TA, can be expressed as the sum of the individual times:

\[ TA = TU + TS + TL + TI + TR \]

Additionally, the researcher also noted the number of keyboard/mouse clicks for accomplishing each tasks.

4.2.2 Evaluation Method

A questionnaire was used to elicit responses from the participants as they performed the assigned tasks. A pilot study was conducted to test various aspects of the evaluation procedures on 28 October 2001 with six DIS student volunteers. Timings were noted for each activity and used as a basis for planning data collection sessions for the study. The pilot study played an important role to identify users’ understanding of the tasks, clarity of task descriptions, plausible problems in obtaining the correct answers for the tasks. Following the feedback from the pilot studies, no major changes were made in the questionnaire. Minor changes made included those of task description wordings and the re-arrangement of tasks in the questionnaire.

The main data evaluation commenced in the first week of November 2001 and lasted till the third week of January 2002 (10 weeks). Data collection was done at different times of the day depending on the participants’ availability. Network problems accessing Internet occurred intermittently. In such instances, the last task prior to the problem was redone, and the evaluation proceeded as normal. The collected data were first entered in MS Excel which was used to code, sort, retrieve and display data for further analysis and for planning the subsequent evaluation. These data were subsequently transformed into a suitable form for detailed statistical analysis using SPSS.

4.2.3 Evaluation Environment

The 10 evaluation tasks were designed with different characteristics. Two sets of such tasks were formulated to ensure that the participants were not using identical tasks when evaluating the second approach. Although the task characteristics were identical, the content and desired information outcomes were different. This was basically needed to avoid the influence of memory effects. For each completed task, participants were asked to rank on a 5-point Likert scale, the usefulness of the organization of information resources, and retrieval effectiveness for the task. Additional questions were also incorporated to obtain further feedback on the characteristics of each approach.

As in most standard evaluation studies, a pilot study was conducted to trial run the evaluation and to finalize the data collection instruments prior to the actual data collection. A total of 60 graduate students
of DIS participated in the evaluation. Repeated measure technique was employed for the evaluation. The participants were divided into 3 groups of 20 students each. Each group was asked to evaluate two different approaches with the task-based approach being commonly evaluated across all 3 groups (i.e. AR-TB, SC-TB, HY-TB). Since each participant evaluated two different approaches, the tasks scenarios for the second approach were modified slightly to avoid the influence of memory or practice effects. Each participant was assigned a unique user identification (ID) and the corresponding IDs were used throughout the data collection and data analysis stages. To avoid order effects, even numbered participants evaluated TB followed by AR/SC/HY, and vice versa for the odd number participants. The nature of the task and evaluation forms used, however, remained identical in this second half of the evaluation. Each evaluation session varied between 90 to 120 minutes. A total of 1200 tasks (200 each for AR/SC/HM and 600 for TB) were carried out by all participants during the 3-month period of data collection. This is deemed a reasonable number for statistical analysis. The collected data were first entered in MS Excel which was used to code, sort, retrieve and display data for further analysis and for planning the subsequent evaluation. These data were subsequently transformed into a suitable form for detailed statistical analysis using SPSS.

4.3 Methodological Assumptions and Limitations

There were a number of methodological assumptions were made in the DWE evaluation study. The sample size of the evaluation study was reasonably good (60). The sample size could have been increased to provide a better representation of the user population to yield even more concrete findings. Nonetheless, the sample size was capped at 60 due to practical problems of searching.

In evaluating digital libraries, system characteristics such as the speed of information retrieval might have an impact on the evaluation results. The speed depends on many aspects such as computer speed, computer RAM, network load and operating speed, and limitations of communication devices, all of which were basically factors that cannot be controlled as we are dealing with real-time Internet evaluation. The above impact of the system efficiency was not measured and documented in this study.

5. Findings and Discussions

The major findings of this evaluation study are presented and discussed in the following sections.

5.1 Participants Profile – Demographic Data

There were an equal number of 30 male and 30 female participants. The majority 53.4% (or 32) participants fell within the age range of 20-29 years, followed by 40% (24) between 30-39, 5% (3) between 40-49 and 1.6% (1) who is 50 or over. A total 86% (or 52) of participants had 4 or more years of computer experience. In terms of using digital resources, 81.7% (or 49) of participants had experience using online databases, 78.3% (47) in e-journals, 71.7% (43) in digital libraries, 68.3% (41) in CD-ROM databases and 36.7% (22) in e-books. As such, the participants’ interaction with computers and digital resources are relatively mature and high.

5.2 Information Resources Location Time

Table 1 shows the time to locate information resource for all the evaluation tasks using the different information organization approaches. It shows the maximum, minimum and mean time taken to locate information resources for each task in seconds together with standard deviation values. For 8 out of the
10 tasks, the participants took less time to identify the relevant information resources using the task-based approach over other approaches. The alphabetical resource approach was faster for the remaining 2 tasks.

Table 1. Time Taken to Locate Information Resources (in seconds)

<table>
<thead>
<tr>
<th>Task</th>
<th>Max Time</th>
<th>Min Time</th>
<th>Mean Time</th>
<th>SD</th>
<th>Task</th>
<th>Max Time</th>
<th>Min Time</th>
<th>Mean Time</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AR 158</td>
<td>29</td>
<td>62.50</td>
<td>29.32</td>
<td>2</td>
<td>SC 108</td>
<td>27</td>
<td>62.55</td>
<td>20.48</td>
</tr>
<tr>
<td></td>
<td>HY 69</td>
<td>15</td>
<td>41.70</td>
<td>15.58</td>
<td>3</td>
<td>HY 69</td>
<td>18</td>
<td>35.65</td>
<td>16.75</td>
</tr>
<tr>
<td></td>
<td>TB 61</td>
<td>16</td>
<td><strong>34.78</strong></td>
<td>10.76</td>
<td>6</td>
<td>AR 158</td>
<td>29</td>
<td>62.50</td>
<td>29.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>SC 234</td>
<td>45</td>
<td>111.15</td>
<td>51.30</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td>8</td>
<td>HY 88</td>
<td>18</td>
<td>35.65</td>
<td>16.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>TB 150</td>
<td>12</td>
<td><strong>25.05</strong></td>
<td>18.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>TB 160</td>
<td>28</td>
<td>67.53</td>
<td>27.98</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TB 161</td>
<td>16</td>
<td><strong>47.03</strong></td>
<td>24.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TB 162</td>
<td>16</td>
<td><strong>47.03</strong></td>
<td>24.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TB 163</td>
<td>16</td>
<td><strong>47.03</strong></td>
<td>24.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TB 164</td>
<td>16</td>
<td><strong>47.03</strong></td>
<td>24.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TB 165</td>
<td>16</td>
<td><strong>47.03</strong></td>
<td>24.51</td>
</tr>
</tbody>
</table>

Note: AR – Alphabetical Approach (n=20); SC – Subject Category approach (n=20); HY – Hybrid Model (n=20); TB – Task Based Approach (n=60). Total number of participants = 60;

Mean time taken to identify information resources i.e., cumulative time taken for understanding the evaluation task (TU), time to select an approach (TS) and time taken to identify information resources (TL), for the ten evaluation tasks are graphically represented in Figure 11. This shows that the TB approach performed the best among the four approaches followed by HY. It was noted that participants who were using HY actually used TB for most of the time. SC performed worst in all cases. From the figure, it can be seen that the mean time taken to locate information resources using SC is always higher than that in other three approaches.

The findings in this section clearly show that the task-based approach saves user time in locating relevant electronic information in comparison to the other approaches. This is an important
feature of the DWE design, since locating the relevant information within a short time is a major challenge in an electronic environment.

5.2 Univariate Analysis

The univariate tests carried out for the different approaches against information resource location time showed statistical significance \((F_{2,54} = 17.51 \text{ and } p < 0.0001)\). The univariate test of within subject effects also shows that there is statistical significance within non-task based approaches and task-based approach \((F_{1,54} = 105.46 \text{ and } p < 0.001)\). Influence of the three non-task based approaches on information resource location time also showed significance \((F_{2,54} = 38.59; p < 0.001)\). Further analysis was therefore carried out to explore these statistical significance results.

A stepwise multiple regression analysis on individual task was done followed by the univariate analysis to find out which independent variable (namely participant’s age, computer experience and digital resources experience) is the best predictor, the second best predictor, and so on, in terms of time to locate information resources for each task. This analysis showed that the dependent variable, location time, is also linked with the participants’ age, computer experience and digital resources experience.

In the regression analysis, the time taken to locate information resources in all the three models were entered first and explained 34.4% of the variance in location time \((F_{3,116} = 20.29, p < 0.001)\). Interaction of SC and age was entered second and explained a further 10.7% \((F_{1,115} = 22.43, p < 0.001)\). Interaction of SC and computer experience was entered third and explained a further 4.7% \((F_{1,114} = 10.55; p < 0.002)\). Interaction of AR approach and computer experience was entered fourth and explained a further 3.1% \((F_{1,113} = 7.46, p < 0.007)\). As such, it can be seen that the information resource location time was greatly associated with age and computer experience for Task #1.

Similarly, the regression analysis was also carried out for the remaining 9 tasks. In general, it is observed that order of evaluation, computer experience, age and gender have influence on the time required to locate the required information to accomplish these tasks. This is an important finding and has a major significance as the general trend in the HEI is to move towards an electronic learning environment. Further research needs to be conducted to specifically assess the impact of these parameters on the overall access to, and use of, electronic information.

5.3 Usefulness of Organization of Information Resources

This section of the findings reports the participants’ preference for the four different approaches to digital information resources organization of DWE according to the assigned tasks. Participants’ qualitative comments for each task are interesting. Instead of discussing them individually, we merged the responses for these evaluation tasks as groups. Participants were asked to rate the usefulness of information resource organisation for each task being evaluated using a scale of 5 to 1 corresponding to Very useful, Useful, Average, Somewhat useful and Not at all useful. For the evaluation tasks #1, #2 and #3 (Series 1) responses of the participants were grouped for analysis and presented in Table 2. The responses of the participants for tasks #5, #7 and #9 (Series 2) were grouped and presented in Table 3. Task-based approach responses for tasks #4, #6, #8 and #10 (Series 3) were grouped and presented in Table 4. These series were grouped according to the nature of task characteristics so that Series 1 was intended to be more amendable to using the AR approach, Series 2 using the SC approach and Series 3 using the TB approach. As such, the findings would give us some indications of the appropriate of these groupings and the respondents’ perception and preference of using the different approaches to accomplish different tasks.
Table 2. Usefulness of the Organisation of Information Resources – Series 1 (AR)

<table>
<thead>
<tr>
<th></th>
<th>Very useful</th>
<th>Useful</th>
<th>Average</th>
<th>Somewhat useful</th>
<th>Not at all useful</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>AR  (n=60)</td>
<td>18</td>
<td>30.0</td>
<td>31</td>
<td>51.7</td>
<td>9</td>
</tr>
<tr>
<td>SC  (n=60)</td>
<td>6</td>
<td>10.0</td>
<td>32</td>
<td>53.3</td>
<td>14</td>
</tr>
<tr>
<td>HY  (n=60)</td>
<td>19</td>
<td>31.7</td>
<td>34</td>
<td>56.7</td>
<td>5</td>
</tr>
<tr>
<td>TB  (n=180)</td>
<td>49</td>
<td>26.7</td>
<td>98</td>
<td>54.4</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 2 shows that more than 81.7% of the participants expressed the AR organisation of information resources as either very useful or useful to complete the evaluation tasks followed by 81.1% in TB approach and 63.3% in SC approach. More participants (88.4%) said the HY approach were very useful or useful to retrieve information for the evaluation tasks than in other approaches, and 13.4% participants less preferred the SC approach by saying somewhat useful or not at all useful to identify answers for the evaluation tasks designed to test alphabetical organisation of information resources.

Table 3. Usefulness of the Organisation of Information Resources – Series 2 (SC)

<table>
<thead>
<tr>
<th></th>
<th>Very useful</th>
<th>Useful</th>
<th>Average</th>
<th>Somewhat useful</th>
<th>Not at all useful</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>AR  (n=60)</td>
<td>10</td>
<td>16.7</td>
<td>18</td>
<td>30.0</td>
<td>20</td>
</tr>
<tr>
<td>SC  (n=60)</td>
<td>2</td>
<td>3.3</td>
<td>34</td>
<td>56.7</td>
<td>20</td>
</tr>
<tr>
<td>HY  (n=60)</td>
<td>17</td>
<td>28.3</td>
<td>36</td>
<td>60.0</td>
<td>7</td>
</tr>
<tr>
<td>TB  (n=180)</td>
<td>49</td>
<td>26.7</td>
<td>105</td>
<td>58.3</td>
<td>24</td>
</tr>
</tbody>
</table>

From Table 3, it can be seen that participants preferred again the HY approach (88.3%) followed by the TB approach (85%) by commenting either very useful or useful. In this respect the SC approach came as the third choice (60%) and AR as the last (46.7%). This result was somewhat unexpected. Out of the 180 participants, only one participant said that the TB approach was somewhat useful.

It can be seen from Table 4 that the HY approach was preferred by 87.6% as very useful or useful, followed by the TB approach (78.7%), the AR approach (72.6%), and the SC approach (61.3%). Only 2, out of 240, expressed that the TB approach was less useful. Overall, the participants preferred the HY approach as this includes all the other three approaches.

Table 4. Usefulness of the Organisation of Information Resources – Series 3 (TB)

<table>
<thead>
<tr>
<th></th>
<th>Very useful</th>
<th>Useful</th>
<th>Average</th>
<th>Somewhat useful</th>
<th>Not at all useful</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>AR  (n=80)</td>
<td>17</td>
<td>21.3</td>
<td>41</td>
<td>51.3</td>
<td>13</td>
</tr>
<tr>
<td>SC  (n=80)</td>
<td>1</td>
<td>1.3</td>
<td>48</td>
<td>60.0</td>
<td>24</td>
</tr>
<tr>
<td>HY  (n=80)</td>
<td>23</td>
<td>28.8</td>
<td>47</td>
<td>58.8</td>
<td>9</td>
</tr>
<tr>
<td>TB  (n=240)</td>
<td>56</td>
<td>23.3</td>
<td>133</td>
<td>55.4</td>
<td>48</td>
</tr>
</tbody>
</table>
Overall, the hybrid approach and the task-based approach to information access were considered better than the other approaches for almost all the tasks. Table 5 shows the overall ratings on the four approaches. It can be seen from the table that the TB is the most preferred approach since 90% of the participants considered it as either very useful or useful. The HY and AR approaches were considered as very useful or useful by 80% of the participants, whereas the SC approach was notably less favoured (65%). Not only most users preferred the TB, but also none rated it as not useful.

Table 5. Overall Rating/Comments on the AR/SC/HY/TB Approaches

<table>
<thead>
<tr>
<th>How useful is the AR/SC/HY/TB Model</th>
<th>Very useful</th>
<th>Useful</th>
<th>Average</th>
<th>Somewhat useful</th>
<th>Not at all useful</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>---</td>
<td>------</td>
<td>---</td>
<td>--</td>
<td>----</td>
<td>---</td>
</tr>
<tr>
<td>AR (n=20)</td>
<td>1 5</td>
<td>15 75</td>
<td>3 15</td>
<td>1 5</td>
<td>0 0</td>
</tr>
<tr>
<td>SC (n=20)</td>
<td>1 5</td>
<td>12 60</td>
<td>4 20</td>
<td>1 5</td>
<td>2 10</td>
</tr>
<tr>
<td>HY (n=20)</td>
<td>9 45</td>
<td>7 35</td>
<td>2 10</td>
<td>1 5</td>
<td>0 0</td>
</tr>
<tr>
<td>TB (n=60)</td>
<td>18 30</td>
<td>36 60</td>
<td>6 10</td>
<td>0 0</td>
<td>0 0</td>
</tr>
</tbody>
</table>

6. Conclusion

The major objective of this research was to design a user-centred DL. Taking into account the current practices, and the gaps, in the DL R&D and the user requirement analysis, this research proposes a novel approach to the design of a DWE. The uniqueness of the DWE design includes the following:

1. Unlike a typical digital library that mainly provides access to the digital library and web resources, DWE is one-stop window for access to digital library, web and internet resources, the later being more and more useful in an electronic learning environment;
2. The task-based information access system is considered by the users to be more useful compared to the traditional approaches to information organization and access; and
3. The model can be adopted in any academic institution with little or no modifications in the overall design principles.

The novel design of DWE thus contributes towards the design and development of better digital libraries for the future. The prototype DWE appears to have an encouraging performance in an HEI setting, though it is expected that this model will be equally useful in corporate and public institution settings, since the basic objective the system is to provide a one-stop access to all kinds of internal and external information resources relevant to a chosen task. Further research in this area should include more testing of the DWE model in different university and institutional settings focusing mainly on the management issues, such as the time and resources required to build and manage the system. Although specific figures were not kept, experience shows that the initial investments in terms of building the system will be high, since significant amount of human efforts are involved in building the task and resource management modules. However, once built, the system can run with very little maintenance costs, since the tasks and the major information resources required to accomplish them do not change significantly in an institutional setting, and many tasks within the system, e.g. tracking the user and resources can be done automatically by simple programs and table lookup procedures.
References


