A User Study of the Design Issues of PROPIE: A Novel Environment for Enhanced Interaction and Value-adding of Electronic Documents

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Abstract

In this paper, we present a proposed information environment (PROPIE) for enhanced interaction and value-adding of electronic documents (e-documents). The design of PROPIE was based on a thorough user needs and requirements assessment in interacting with information through well-documented findings, and a focus group with twelve participants to elicit features that were deemed desirable in future interactions. The design was also based on an earlier work which reviewed the advancements in various user interface (UI) technologies, visualisation and interactive techniques, and a consideration of novel information structuring and organisation techniques that pose important implications for the design of more advanced UIs.

Providing a suite of novel features and interactive tools that can be flexibly combined, PROPIE allows users to apply multiple novel ways to intuitively query and navigate information in an e-document. The querying and browsing processes in PROPIE are supported by various interactive and visualisation techniques. Users work within a visually sovereign, integrated environment for information gathering and organising, based on navigable, fractional information objects that are also affiliated with rich metadata and additional layers of value-adding information. A set of interface mock-ups was developed to demonstrate the potential of the environment in supporting the design of a new generation of electronic journals (e-journals). We report here empirical results from a study conducted to obtain representative users’ feedback with regard to using PROPIE for interacting with e-journals. Twenty two participants from a variety of academic background participated in the evaluation. Overall, PROPIE was found having the potentials in both enhancing user’s interaction with information captured within e-journals and in adding value to e-documents in various ways.

1.0 Introduction

In the words of Bolter [1], the demise of printed pages is inevitable. A similar prediction is articulated by Odlyzko [2, p.96]:
“I expect that scholarly publishing will move to almost exclusively electronic means of information dissemination. The will be caused by the economic push of increasing costs of the present system and the attractive pull of the new features that electronic publishing offers.”

There has indeed, been a prominent upsurge of interest in the past few years in the idea of escaping the static and rigid constraint of paper through digital alternatives. Many others involved in e-journal projects, for instance, believe very strongly that e-documents represents the pattern for the near future [3, 4, 5].

The reasons for the upsurge of interest in e-documents lie in part in the rapid advances in direct manipulation (DM) technologies and interactive techniques in the past 15 years that have provided the foundation for much more elaborate interactions with documents through graphical or visual interfaces [6, 7]. Another factor is the shift in information becoming ever more digital, enabling for instance, more uniform interaction where all formats can now be stored and sent equivalently. Information is also making its structure increasingly accessible as text and metadata formats move to SGML (Standard Generalised Mark-up Language) [8]. The granularity of information packaging has also become variable, shifting the model of documents from passive streams of characters to malleable collection of meaningful objects. Likewise, the requirement to deal with a massive electronic world and the emergence of distinct structure has led to fractional, modular [9], layers [10] of information organisation. This paradigm shift consequently results in the disaggregation of documents into separate component [11] and the need to interact with information at many different scales.

Given these parallel developments however, one of the remarkable features of today’s e-documents is that few of them actually make use of the special features of the electronic medium in novel ways to scholarly intellectual advantage, except for distribution. Most of the e-journals for example, publish articles that could appear in paper journals. With a few exceptions, e-journals exist in a kind of ghostly nether-world of academic publishing. Despite the propagation of technologies, new publishing tools and networked-based telecommunications, print has remained the preferred medium of many, especially for ease of reading. Hence, for e-documents such as e-journals to be truly valuable to users and to contribute to scholarly communication, e-documents need to be more that a mere electronic mimic of their print counterparts. They will need to be as indicated by Odlyzko [12] and Holoviak and Seitter [13], to be adding values in their online forms and to go beyond the capabilities of the printed pages. In contrast to the views of some electronic publishing enthusiasts such as Bolter [1] and Odlyzko [2] who argue that print documents will disappear within 10 to 20 years, we view both electronic and print documents as partners in fulfilling a set of useful communicative functions. Each medium complements each other, providing a package that is convenient for certain purposes and awkward for others (e.g. ease of reading for print journals, and enhanced distribution, searching and collaborative works for e-journals). The future of e-documents will likely be enacted through electronic enhancements and value-added features to their print counterparts.
Many recent works [14, 15, 16] have indeed, called for a breakthrough - indicating the need to more fully exploit the potential of the electronic environment to further improve and enhance user interaction with e-documents such as e-journals to significantly enrich scholarly communication.

2.0 Study Overview

Earlier studies of enhancing interaction with e-documents have mostly focused on isolated solutions. Some of these works have looked into specifically the information presentation aspect [9, 17] while others deal with providing access to additional information via means such as hyperlinks [14, 18]. Some researches into e-journals are also increasingly addressing the possibilities of transcending the limitation of the printed journals to include unprintable materials – such as multimedia files that contain audio, video, animation and 3D graphics [13].

Many new interactive techniques, visualisations and applications have also emerged as a result of the need to support a wide variety of basic information manipulation and analysis tasks. Some applications support for instance, creating new information and visualising relationships among them [19]. Others support controlling the level of aggregation of data and rapid filtering of data subsets [20, 21]. Still others support navigation through large data spaces [22, 23, 24]. A fundamental UI design question this study is addressing is how one can use the complimentary features of various visualisation, interaction and analysis tools in a uniform and co-ordinated manner. Even for just these few example activities for instance, can a user create new data attributes with one tool, filter the same data with another and visualise the resulting subsets with a third tool?

This study seeks to examine the broader problem of supporting the wide range of information searching, analysis and communicating tasks involved in interacting with e-documents within a single UI environment, using e-journals as an example of e-documents. We aim to explore the potential and impact of an innovative information environment where users can make seamless transitions in their utilisation of multiple tools, visualisation and interactive applications to meet their various needs, and to ultimately, support the value-adding of these e-documents. The study is carried out in three major stages:

1. A background and empirical investigation (needs assessment) stage – a review and analysis of related works and elicitation of user needs and requirements (through a focus group)
2. PROPIE conceptual design and prototyping stage – conceptual design of the environment and the task scenarios for the subsequent empirical evaluation
3. PROPIE evaluation stage – an empirical and formative evaluation of the proposed environment by representative users.
3.0 Research Questions

The overall objective of the study is to help make a new generation of e-documents a realism (Figure 1). A central element of our study and approach is to provide users of e-documents with multiple means for expressing their intentions during various information-seeking tasks. ‘Multiple means of expression’ in this context refers to visualisation and interaction techniques that are useful for different purposes, but are often effective when used in combination as they support representations of different kinds of objects, actions and goals.

![Figure 1. Making the leap to a new generation of e-documents.](image)

This study aims to explore and answer the following two main research questions:

1. Can an innovative information environment be introduced to enhance user interaction with e-documents by facilitating new ways to manipulate digital information - to enable users to view and use information in different ways to perform various tasks and hence, to fulfill various needs?

2. Can this newly proposed information environment be adopted to add-value to e-documents by enabling users to perform a variety of tasks that might have been difficult or impossible in current electronic versions of documents?
Design considerations for such an environment were explored, based on an understanding of user needs and requirements in interacting with information, and the technologies that were available to support the desired interactions. In addition, a focus group with twelve participants was conducted in the needs assessment phase to further elicit user interaction needs and requirements. Following this, a set of desired properties for both the interaction environment and the information objects within the environment was identified [25]. These properties are summarised in Table 1. They subsequently formed the foundation features for the design of PROPIE. Following that, an evaluation of PROPIE was conducted.

In the remainder of this paper, we first discuss the review of related works and summarise the focus group study results. We then describe the evaluation conducted, following by presentation of the findings, and discussion of the results. Finally, we discuss further works to be conducted.

4.0 Review of Related Works

Understanding the electronic information environment requires an awareness of the information system, the user needs and the technologies that are available to support user interaction with information. Hence, issues in the design of interactions with value-added e-documents arise from three main sources:

- increasing knowledge of how users interact with (seek and use) information, and the tasks they perform to achieve their goals;
- the ongoing advancement of the information world, leading to a new paradigm of electronic information; and
- the developments in UI technologies that have provided the basis for much more elaborate interactions with the underlying information world.

As such, the review and analysis of related work is presented along these three inter-related areas.
### Table 1. Interaction environment & information objects properties.

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<th>Interaction environment properties</th>
<th>Properties</th>
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<tr>
<td>Properties that are closely associated with the interaction environment.</td>
<td>(1) <strong>Integration of workspace</strong> - the information environment should integrate both the user’s personal workspace and the broader information world to allow a tighter connection between the user’s own larger task that is normally centered in the private workspace, and their information-seeking sub-tasks that are often focused in the broader information world.</td>
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<td>(2) <strong>User-controlled malleability</strong> – the environment must support direct manipulation to enable natural, interactive access to the various information objects and tools.</td>
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<td>(3) <strong>Visual sovereignty</strong> - the environment should also provide the user with visual representation to the various conceptual items of the user’s information-seeking task (e.g., a collection of information objects related to the task, or the user’s search and browse history records). Providing such ‘total view’ while searching gives the user satisfaction of being able to perceive the existence of related objects, be made aware of their status and be able to act upon these according to their needs.</td>
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<td>(4) <strong>Multiple representation/views</strong> - multiple representation of information objects and their organizations should also be a part of the environment, so as to support a variety of task and information-seeking perspectives.</td>
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<td><strong>Integration with appropriate tools</strong> - the environment should also provide tools for basic common interactions which include querying for information, the more heuristic navigation through information space, organizing and authoring information. The environment should enable intuitive and easy means for users to move back and forth between the more informal cursory process and the more detailed, focused efforts in information searching and analysis.</td>
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| Information object properties | (1) **Structured** - information objects should have structures both internal and external to themselves. They for instance, can contain or be enclosed in sets, collections or ordered lists, tables, trees, natural language sentence structure, paragraphs or chapters. These objects should make visually explicit their internal structures (e.g., as to navigate over) to help users in the information searching process. They should also state explicitly where they fit into various larger structures. |
| | (2) **Fractional** - ensuring the notion of ubiquitous internal and external structure is an almost fractional nature to the information objects representation. Objects should also allow manipulation and interaction at all levels of granularity in a coherent manner. |
| | (3) **Queriable and navigable** - all objects in the infosphere at any granularity should also be queriable and navigable. |
| | (4) **Explicable** - as in general, information searching and knowledge work is a temporarily prolonged process, with information seekers often moving back to previous work done and building on it, all objects should ideally come with representations of their history – where they originate from and what operations have been performed on them. The historical sequence of the objects generated should be in a visualizable, malleable history mechanism. |
| | (5) **Contextualized** - information objects should make various aspects of their context such as relationships between various contents (both established by system and the user) available to the user, to enable better understanding of both the objects and the environment. This is important to support the context-driven evolution of a user’s interests. |
| | (6) **Affiliation with metadata and additional layers of information** - evaluation, reviews, commentaries and criticisms are all value-adding properties that provide information seekers additional information for decision-making. Annotations on all objects at any granularity, both for personal and shared use should also be supported. This will become even more important when people no longer work in isolation, and where technology is used for collaborative work. It is evident that all the information objects should also be associated with a large prescription of metadata to implement many of the discussed properties. Metadata can also be used to effect value-adding to objects. Examples of meta-level value-adding include: |
| | • Information customization (e.g., non-prescriptive, non-linear document traversal, variable links and integration of sources) and |
| | • Searching, indexing and database technologies (e.g. provide dynamic, real-time analysis for document clusters, with innovative mining and clustering topologies for display of results). |
4.1 User information interaction and needs analyses

Adopting a user-centred approach to information system design requires an understanding of user needs and their real interactions with information. Attention to users of digital information systems and their needs from a communications perspective have been well presented as various models in literature. For the purpose of this research, a subset of these proposed models that holds more direct implications on the design of interactive interfaces for end-users are presented and reviewed. Alongside the review, the significance of these findings on the design of the information environments for future e-documents is identified.

Belkin and colleagues [26] propose that information systems need to capture users’ Anomalous State of Knowledge (ASK). According to the ASK model, users must go through a process of clarification to articulate a search request, with the obvious implication that electronic systems should support the iterative and interactive dialogues with users that include for instance, the goal of interaction (learn/select), method of interaction (scan/search), mode of retrieval (recognise/specify) and type of resource (information/meta-information) [27, 28]. The system must therefore allow users to scan, recognise, learn and select, amongst others.

Bates [29] proposes a berrypicking model to illustrate the evolving search process in using online and other information systems. Bates focuses on and describes the browsing concept and subsequently develops six strategies associated with this concept, namely, footnote chasing (‘backward chaining’), citation searching (‘forward chaining’), area scanning, subject searching in bibliographies and A&I (abstracting and indexing) services, and author searching. Every new piece of information the searchers encounter has the potential to provide them with new ideas and directions to follow. This model depicts the need for interfaces to support these strategic, opportunistic interactions with information. Robins [30] similarly concludes in his study that users work toward search goals in non-linear fashion, spending about 60% of their time in switching between search strategies and evaluating search outputs based on bits of information they encounter.

Another researcher, Ingwersen [31] proposes a poly-representation approach in information retrieval where user’s cognitive space not only represents user’s current (often topical) information need, but also more importantly, the underlying problem space, actual work task or interest, and the dominant work domains. This approach implies that different methods of representation and a variety of search and retrieval techniques of different functional origin should be available simultaneously to each semantic entity in an electronic system. However, user interactive process, such as that of feedback, are only implied processes within this model. The challenge for a more interactive model is to elaborate and incorporate feedback and user judgements concerning for instance, query reformulation, visualisation and navigation.

Cool and fellow researchers [32] discuss one particular type of interaction with text - that with the goal of evaluating usefulness. This involves looking first at
characteristics of the text such as author or title, to determine the topical relevance of a specific document. Meanwhile, Belkin [33] examines another type of interaction – that with the goal of discovery, whereby users scan the whole texts widely or part of the text to determine its relevance. These two studies indicate two different requirements on text representation and structuring in support of effective interaction with information. The formal study shows that characteristics of secondary texts will need to be represented and related to one another, and other attributes of texts, in forms that can be used in ways other than for bibliographic specification, or as retrieval leads. The latter study indicates that facilities for dynamic, user-defined and large scale patterns in texts are required, and patterns should be capable of being related to other sections of the texts through dynamically established clusters or links.

The information foraging model by Pirolli and Card [34] attempts to explain how various system design criteria could affect the balance between the value of information gained and the user’s cost of performing various activities under the different designs. Pirolli [35] later presents a more elaborate description of the technique and its application to exploring the design space for a browser for very large text repositories. This approach permits the exploration of “what-if” design scenarios and the exploration of changes in ideal user strategies across system and task conditions.

Saracevic [36] recommends a stratified model of interactive information retrieval. Interactions between the actors (i.e. users, computers and intermediaries) are believed to be sequences of processes advancing at different interconnected levels or strata. At the surface level, dialogues between users and systems are captured, where users express their needs with the computer and the computer responds with results. At the cognitive level, users interpret information provided by the system. At the situational level, the context or situation in which users approach the system motivates the interaction. The different strata are closely interrelated and are extremely dynamic with each move by the user or system influencing other moves or shifts within interactions, such as information problem, strategies, feedback or uncertainty. This leads to major implications for interface design whereby a user’s relevance judgements and search episodes (i.e. interactions with systems) must be visually analysed and presented to the user in a visible manner.

Apart from these generic models, a subset of relevant studies that concentrates on end-users of e-documents exists. Dillon [37] acknowledges the differences between using a print document and its electronic counterpart. He concludes that future e-documents will need to have more powerful navigation and manipulation facilities to support the task users need to perform, to effectively use these e-documents. Studies of end-users are sometimes part of an overall development effort for a specific electronic system [38, 39, 40]. Generalised results from these studies essentially elucidate the high acceptance of interactive browsing and navigation by typical end-users as the main strategy employed in using e-documents. Among the features identified as important support that a system must provide are:

- to help in the user question-negotiating process,
to allow the user to pursue multiple approaches of inquiry by entering fragments of the question,
to allow the user to explore multiple navigation options, and
to capture partial results – modelling the user’s current interest and perhaps, suggesting the next navigation choices according to the nearness of this interest.

While examining the social, economical and political contexts of designing genres for new media, Agre [41] proposes that the new media be designed to “do more”. He calls for a consideration of how the new medium might do more for users than the ones they already are using. For instance, the new medium might be designed to ease certain functions (e.g. searching, sorting or comparing and pooling group efforts) that the users now perform laboriously for themselves, or that they rarely carry out because it is so arduous. Hence, in Agre’s opinion, the new genre of e-documents must not simply deposit information in a mass, but to arrange information in a rationale, intelligible form and to provide functionality to support users’ enriched interactions with information in its digital form. Others who share his view are Kling and Covi [42] who are convinced that the paper and electronic medium bear significantly different material properties and e-journals that thrive will mostly be those where enhanced electronic virtues have been added to contribute to novel scholarly communication systems.

The way information is presented to the user is also a crucial issue. To deal with the common information overload and screen cluttering problem, Kreitzberg [17] proposes a “just enough up front, details on demand” paradigm in designing e-documents. He suggests providing just enough information at first to ensure comprehension and presenting information in a logical sequence so that the information which has come before provides context for that which follows, and imparting details to users on demand. Kreitzberg’s paradigm stresses the importance for information units to maintain conceptual integrity and comprehensive coverage, by treating each unit as an initial presentation, which links to pre-requisite concepts required for understanding, and avoids cluttering the presentation with unnecessary details.

The Open Journal Project [14, 43] that is concerned with user interaction with e-journals has received a number of interesting reviews from its access demonstration of citation linking in the Open Journal of Cognitive Science in April and May 1998. Users generally favour the link structure and demand for more links to trace ideas and in serendipity searches. They also call for better orientation and additional navigation aids to keep track of where they are in the clusters of links. Dillon, Richardson and McKnight [44] also note that users generally first select and scan sections of a journal article before judging the relevance and probable quality of the document. While scanning through the article, users often prefer to maintain an overview of the whole article while exploring the different sections (e.g., introduction, section headings, diagrams/tables and conclusion) before deciding to read on, or to reject the article. The implication for the design of e-journals is that the system must support this exploration while providing an overview, and offer features to help users to decide the relevance of the article, or to perform other tasks. Such features can include for instance, display explicitly a list of other papers citing the current article, word or phrase dependencies and occurrences within the article,
and display a list of other works published by the article’s author(s). All these features add value to the information while maintaining an overview of the context. As researchers begin to move toward collaborative work, support of annotations both for personal and shared use may also be desirable. If users of e-journals are to find required and desired information more quickly and better-placed in context, future e-journals will have to strive for completeness of information presentation and be supported by advanced technologies in the organisation and presentation of the information.

In other studies of e-journals such as the Café Jus [45] and the SuperJournal Project [46], the predominant view is that e-journals are useful for easy and convenient access, and for quick scanning and searching. Although print journals are largely preferred for lengthy reading, interactive features in the electronic counterparts to support comprehensive access and searching are appreciated, and more enhancements are greatly anticipated.

In addition to the major user-information interaction models and understanding the user needs and requirements, it is also necessary to examine the UI requirements. Between the analytical and browsing strategies of searching, this study emphasises on the more heuristic browsing strategy, particularly, in improving the user interaction with information units within e-documents. Hence, tasks such as hierarchical traversal, cluster-based traversal, dynamic links traversal, panning and zooming for context and details, and accessing a variety of information sources in a seamless manner becomes more significant in this context. Shneiderman [47] proposes a framework of seven tasks that form the basic interface features that the next-generation information systems interface should support. The framework is believed to encompass the major functionality required to support effective user-information interaction in this research. These seven tasks are overview, zooming, filtering, details-on-demand, relate, history and extract.

An overview provides a good starting point for the user to “scan and select” and to provide the overall information context. Smooth zooming helps users to maintain their sense of position (context) while exploring the various links or sections within an e-document. Filtering is used to weed out uninteresting or unnecessary details in a document or collection to help users focus on relevant details. Details-on-demand provides the option to allow the user to take a closer look at details (e.g., full-text that stands behind any representation or attached files) of one or more objects in the field of view. Relate makes explicit relationships between objects in a display. It may also refer to representing relationships between data in multiple associated windows. A history is useful to maintain a list of previous actions in order to support place-keeping, undo and for progressive refinement. Finally, extract permits users to extract an item or a set of items of interest from the information context for further exploration.

4.2 Developments in the Electronic Information World

A second area of consideration is the advancement of the electronic information world, where the view of the possibilities for new dynamic information entities and more
advanced interactions with electronic information has been expanded. Information has become ever more digital, enabling for instance, more uniform interactions where all format can be stored and sent equivalently. This has also made it possible for various parties (e.g., author, publisher/information broker and other third parties) to package metadata along with primary content. Metadata is defined as ‘data about data’ – it includes information about the context of data, the content of data and the control of or over data [48]. A simple example of metadata is a library catalogue. The importance of metadata is growing in various niches and applications can utilise metadata to integrate with one another, to exhibit the relationships with one another, and also to manifest the larger context in which they are being used. It is possible indeed, to apply more than one action to an information object, something that currently lies outside the standard World Wide Web paradigm.

The malleability of digital information is further fostered by SGML [49], a meta-language for defining mark-up schemes that provides a means of describing the components of an information object. SGML does not prescribe what processes are to be performed with the object. It is built on the principle that the mark-up is descriptive and not prescriptive. Newer SGML-based metadata formats (e.g., TEI Headers) can be distinguished from the simple structured generic formats (e.g., Dublin Core [8]) by fullness (delving into more details), structure (contain richer structuring schemes) and by specialism (they may be more specific to the relevant domain). They can be used for location and discovery, and in documenting information objects and/or collections of objects. They allow for some level of evaluation and analysis of content, and navigation around aggregations of objects. They are also expressive enough to capture various relationships at different levels of aggregation. However, to make information more apparent to more general resource discovery tools, export of data in some simpler formats such as the Dublin Core may be needed.

The transition from the physical delivery of printed documents to e-documents in the form of bits and bytes over the network has also made the granularity of information packaging variable. This consequently results in the need to interact with information at many different scales. Rayward’s account of Paul Otlet’s “monographic principle” (which Otlet developed around 1920) suggests that the vision of disaggregating documents into individually usable components is not new. Rayward [50] has discussed how the indexing of documents could be at any level of detail. Indeed, in the electronic environment, from super-digital library collections down to individual documents, down to pages, paragraphs and diagrams, even to the level of words, can now be teased apart and be manipulated to get more values out of the different levels of information objects. As we move from an environment where information is transformed from linear to multidimensional form, information objects no longer needs to fit into any physical unit but comprising logical components of information [51], probably built-up of units each of which could stand independently on their own. In such a case, each of these information objects will need to have sufficient descriptive information to enable it to be used in various contexts. SGML is an example that provides flexible structuring capabilities to describe these objects.
With the advent of digital texts and new tools for manipulating them, the fundamental concept of a document is stirred [52], and e-journals and other e-documents are increasingly perceived as interfaces through which creators and users of knowledge interact [53, 54].

These considerations of new forms of information presentation and structuring have important implications for the design of new interface and interaction environment with e-documents. Interfaces are starting to move beyond mimicking mechanisms of earlier media and traditional interface metaphor to more thoroughly exploit computationally-based mechanisms. Mohnkern [55] proposes that while metaphor is useful in providing consistency and structure to work with, it is not the metaphor itself that makes a system successful. There is a need indeed, to break from the metaphor when necessary, especially when the interface needs to perform in a manner that is inconsistent with traditional metaphor. Hence, the emphasis is on the important functions that are required to deal with information that is much more dynamic and reactive to user needs and preferences.

4.3 Developments in UI Technology

Just as the electronic information world has advanced, so have the technologies that form the basis for information worlds. The past 15 years of advances have started to provide the foundation for much more elaborate interactions with the underlying information world - with collection of documents and with individual document through graphical or visual interfaces [6, 7]. Visual displays of information are fast gaining acceptance and recognition [56]. This is so since visual displays are more easily understood, providing an operating environment where an explicit visual and functional context for the computer user’s actions is formed [57]. It is also important to understand at the onset that the user interface is not only a screen design, but a method of interacting with the application and its data. Interaction techniques are hence, an integrated part of visualisation. User interfaces to e-documents that offer greater sophistication and technological mastery in manipulating diverse forms of information will be in great demand. Young generations of computer users are becoming ‘digital sorcerers’ [58] – handling new computer games, software applications and personal digital assistants with ease. Apart from the combined efforts of researchers and user-oriented designers, this phenomenon is also likely to be attributed to the intimacy derived from simply living with advanced technology. It is almost assured that future generations of e-document users, with their grasp of digital manipulation, will demand for new forms of interaction and redefine current notions of creative expression.

A couple of the more recent and more relevant developments in the UI technology that will form the basis for more powerful interaction with future e-documents include the advances of DM interfaces in the 1980’s, and especially, the ensuing emergence of information visualisation (IV) techniques in the 1990’s. DM makes interaction with electronic information more intuitive. Its applications respond interactively to the user’s input actions. Compared to traditional information access tools that are limited in their ability to display results, and often require users to remember obscure command
vocabularies and complicated syntax, DM allows users to visualise and directly manipulate objects on computer screens. Recent works in the 1990’s have carried the user’s desire of manipulating real objects still further. Works on the FilmFinder [59] and the HomeFinder [60] for instance, have shown that users are able to locate information faster than with natural language queries. User comprehension and satisfaction have also proven to be higher for these interfaces.

The success of DM interfaces is known as a manifestation of the power of using computers in a more visual, or graphical manner [47]. Existing IV systems that allows users to zoom, filter and examine details-on-demand capabilities, builds its strength on a similar principle. Users not only desire to find information quickly in the electronic environment, they also want comprehensible and commandable interfaces to e-documents that will provide them feeling of accomplishment and empowerment. Users require a system where the focus is on DM of objects presented, using a virtual reality type of paradigm to promote real-time feedback, and be given intuitive control over where and how the exploration is occurring. Such a system must also support the philosophy of not trying to display all the potentially very large and dense, multidimensional data at once. Users must instead, be allowed to interactively select the fragment of interests and explore selected information. IV are potential tools required to complement and enhance current e-document interfaces. These techniques will enable users to manoeuvre their searching and browsing tasks more efficiently and creatively.

There are parallels between IV and scientific visualisation, in terms of their purpose and their method – the purpose being that of extracting prominent dimensions from multidimensional data, and the method being that of using advanced graphical and animation techniques to present data. Spence [61] points out that visualisation is something a human engages in and that its potential value lies in that of gaining insights and understanding. He describes the function of IV as in presentation and representation, and rearrangement and dynamic exploration of information, whereby human interacts with information to gain dimensionality and perception in order to comprehend.

In the application of IV, consideration needs to be taken that the interesting information are mostly abstract (e.g., information structures and relationships) so that intuitive comprehensible visual metaphors have to be developed. Also, in contrast to scientific visualisation where applications are focused on trained scientists and engineers, interfaces created to manipulate e-documents may be widely deployed amongst a diverse and potentially non-technical population that varies in terms of their levels of education, background, experiences, capabilities, information needs, and the tasks they need to perform. Hence, one of the main goals of the application of IV should be to enable these disparate user groups to use visual presentations that will be tailored to their specific needs. The tools and the interface must also be intuitively easy for each of these groups to handle.

In e-documents such as e-journals that are laden with data and information, appropriate utilisation of IV has the potential to assist users in identifying, exploring, discovering and in developing understanding of possible complex situations in interacting
with e-documents. IV also supports the value-adding of e-documents. The essence lies in its ability to allow manipulation and analysis of both the presentation and attributes of data to produce possibly new information that might not otherwise be obvious or even discernible. A thorough review and taxonomy of some of the existing IV technologies have been carried out. Interested readers can refer to this earlier work [25].

4.4 Summary of Review of Related Works

Based on the preceding reviews and analyses, some pertinent observations become obvious. An innovative information workspace with new interaction approaches is desired for users to interact with electronic data in novel multiple complementary ways. This becomes ever more important as our lives are increasingly being conducted on a base of information technology suffused with computationally cross-accessible information. Users must not be perceived as passive recipients but instead as active composer and manipulator of information. Users must be also allowed to re-organise the information where necessary to create new information that meets their needs. Through the application of these novel tools, value-adding to e-documents may also be achieved.

4.5 Needs assessments focus group study

As part of the needs assessment, a focus group to further elicit user needs and requirements was conducted on 20 July 1999. Twelve participants – part-time Masters students in the Division of Information Studies (DIS) at Nanyang Technological University (NTU), Singapore took part in the focus group. Consistent with many of the findings reviewed above, the results of the focus group discussion showed that while print journals were still preferred for lengthy reading, e-journals were welcomed for their interactive features. Features deemed crucial in e-journals were: searching capability within a document and across a range of related documents; providing look-up links to other sources such as a thesaurus and dictionary; capability to filter unwanted information in display; capability to check details-on-demand; providing context during browsing and searching so as to guide users in their information seeking process; providing links to comments and annotations by other users, and the capability to annotate in a digital document.

These suggested functionality, together with features identified as crucial as the review of related works, contribute to the design of an innovative environment for enhanced access and interaction with e-journals.

5.0 Methodology

Too little is currently made known about the application of various novel interactive and visualisation techniques within one single UI environment to enhance interaction with e-journals (or e-documents) to formulate specific hypothesis. It is not feasible to have subjects performing tasks that can be measured quantitatively (e.g. based on time spent on tasks and error rate) as this study involves the evaluation of design concepts, and not of a fully operational system. Amongst the various types of common
usability tests, exploratory tests match the needs of the exploratory nature of this study as it is aimed at discovering and understanding themes, potential relations and perceptions. Methods that emphasise flexibility, comprehensiveness and understanding are hence, chosen.

A scenario-based approach is used to demonstrate a set of various scenarios of how a novel environment is likely to be used for interacting with e-journals. The scenarios and tasks chosen provide reasonable coverage of the typical and desired information-seeking tasks involved in interaction with journals, and reflect the kinds of tasks an innovative environment would address if implemented as an operational system. Details of the choice of scenarios are presented in Section 7.1. These scenarios act to illustrate the ability of the environment (and the interfaces) to provide enhanced user interaction, and to add-value to e-journals. It is also aimed at demonstrating how in general, digital information and user interaction is likely to be perceived and used in the future. The scenarios are supported by mock-ups of the desired output. Together, they serve as the platform for the empirical evaluation. When the tasks are put into the context of a realistic scenario, a degree of realism and subject involvement is likely to be achieved [62]. This is important especially when a real working system does not exist for subjects to work on, and to base their evaluations on.

6.0 The Proposed Information Environment (PROPIE)

This section provides a brief introduction to PROPIE. A more detailed description of the conceptual design of the environment and the various tools and features available is reported in our earlier work [63]. PROPIE is an integrated and unifying environment comprising of multiple workspaces. Each of the workspaces serves a specific (yet complimentary) function within the environment. The workspaces operate in an independent yet closely co-ordinated manner. Users have the autonomy and flexibility to use either all the workspaces in a unified manner, or to use each of them independently according to different needs. They can for instance, call up only the necessary workspaces, minimise or maximise them, and move the workspaces around in the environment according to their preferences and needs. The ‘body-and-clone’ analogy has been applied in PROPIE design so that the original body of the document is kept intact in one of the workspaces, while allowing information objects within the body (i.e. clones) to be moved to other workspaces for further operations to be carried out on these objects. Figure 2 shows the main interface and the four basic parts of PROPIE.
The InfoSphere Organiser is the part of a wider information work sphere whereby users organise and display their information collections. These include their personal collections of information, or information residing outside the user’s current work space (e.g. collections of journal articles that the user has subscribed to from various digital libraries). Various interaction and visualisation techniques can be applied here to obtain a view into this sphere and the various items in the collections. Users could for instance, want an overview of the items in a collection to quickly select some relevant items, and to be able to extract the information (objects) for further exploration. A search mechanism is in place for user to quickly locate desired items. Users can zoom in on information clusters (e.g., by using a continuous zoom mechanism on a document map view) and navigationally explore the information object collections in detail until they eventually locate the actual desired information (e.g., an article within a journal collection). To further explore an object, user simply drags the object and drops it into other workspaces. This broader workspace is closely integrated with the following user’s personal workspaces.

The Object Viewer is the workspace whereby users get a first glance of the content of the selected object. For instance, once a journal article has been selected and dragged into Object Viewer, users are given an option to either have the first page of the article or only the abstract displayed to get a quick view of the contents of the object. It is closely integrated and co-ordinated with the Structure Viewer/Overviewer. The user can make use of the co-ordinated display and directed-navigation to browse through the document. To further explore an information object, the user can select (e.g. the whole article, a phrase or a diagram within the article) and drop it into the Object Explorer.
The **Structure Viewer/Overviewer** provides an overview display of the object structure. Users are given a set of display options to examine the structure and layout of the object. By default, the display is selected based on the object's inherent structure (i.e. the most suitable display). For example, if the selected object is a set of articles by a particular author, the information may be represented in the form of multiple timeline, showing multiple facets of and relationships between the records using malleable icons. If the object under examination is an article, thumbnail pages of the document are displayed. This workspace also offers users a set of tools to interact with the display, including displaying the information in multiple representations to explore various patterns and to discover potential new information.

The **Object Explorer** workspace is the ‘value-adding’ aspect of the environment that allows users to perform a variety of other tasks to further analyse various information objects. Users can interact with more than one (set of) object simultaneously. The user is able to, for instance, specify one set (e.g., of words) to be used as a query, and another set (e.g., of articles) to be used as the ad hoc collection to be searched on. The system then returns a third set (i.e. matches) which the user can save as a personal collection (in the *InfoSphere Organiser*), or to perform further exploration. Here, users are given a set of widgets (e.g., a set of functional lens, tools to view and add digital comments and annotations, and tools to browse through related works) in the ‘Tool’ menu to interact with various information objects. There is also a ‘History Cabinet’ – serving as a ‘store’ for the user to keep track of search and browse interactions, and a ‘Pocket Register’ – serving as a ‘back pocket’ whereby information objects can be deposited temporarily, staying ready-at-hand while the user explore some other objects in the workspace. These two widgets are governed by certain authorisation (i.e. access control) and protection (i.e. security) mechanisms.

In summary, the single unifying environment with independent yet co-ordinated workspaces and the ubiquitous movement of information objects is meant to enable a more integrated environment to support the carrying out of a sequence of related tasks. Direct manipulation is the fundamental mode of interaction throughout the environment. Tools to enhance information gathering and analysis tasks (e.g. navigation via information layout and structure, and infinite zoom) are incorporated into PROPIE. The information objects within the environment are fractionally structured and can be laid out on the information surface to depict this fractal structure. All objects (each associated with a rich prescription of metadata) at any granularity are queriable and navigable. Objects collected at any of the workspaces can be temporarily stored into the ‘Pocket Register’ that serves as an interactive, multi-object, visible ‘back pocket’ that helps reduce space contention. The ‘History Cabinet’ meanwhile, maintains a record of history for backtracking.

### 7.0 Design of the PROPIE Evaluation

The empirical evaluation of PROPIE was carried out to address the following more specific research questions derived from the two main research questions presented in Section 4.0:
1. What are the tools and associated features proposed in PROPIE that are deemed important and useful in enhancing interaction with e-journals (and in general, e-documents)?

2. What are the concepts and interaction proposed in PROPIE that are deemed value-adding to e-journals (e-documents)?

3. What are the facets deemed inhibiting users’ satisfaction with PROPIE? What are the indications for the design of future e-journals (e-documents)?

4. Is there any other tools/features that should be incorporated into future design of e-journals (e-documents) to further enhance interaction?

7.1 Task scenarios

The use of PROPIE for interaction with e-journals is demonstrated through a typical scenario and some representative displays in which an information science student interacts with e-journals via PROPIE to gather relevant and useful information for a digital library project. The scenario (containing a set of 71 mini scenarios labelled as a ‘100+10’ increment – i.e. T100 (Task 100), T110, T120, and so on.) is extensively intended to demonstrate the use of the various features and tools within PROPIE to support a user’s various interaction needs with an e-journal. A detailed description and illustration of the mini scenarios can be found in [63].

![Alternative views to browse through one’s collections of documents in InfoSphere Organiser](image)

FIG.3. Alternative views to browse through one’s collections of documents in *InfoSphere Organiser*

The task scenario design generally took into account basic tasks involved in typical information gathering and analysis processes, and the more advanced interactions such as...
Shneiderman’s [47] list of visual manipulation requirements (i.e. overview, zoom, filter, details-on-demand, relate, history and extract). Task sets incorporated into the evaluation included those of providing an overview to a document structure, browsing through collections of documents using different display such as a list or a ‘Map’ (Figure 3), seamless access to other information sources such as a ‘Translation’ tool (Figure 2) and a ‘Thesauri & Knowledge Package’ (Figure 4), locating items of interest using different techniques such as a ‘Time Line’ (Figure 5), extracting items of interest, browsing through an item of interest via a range of display options, co-ordinated highlighting navigation via visually co-ordinated workspaces (Figure 6), filtering information to focus on important details, ‘focus + context’ viewing (Figure 7), controlling the amount of information via layers or levels of details, collaborating with other users via for instance, digital comments and annotations, temporarily storing items of interest in the ‘Pocket Register’, identifying and browsing through related work using for example, the ‘Citation Linking’ (Figure 8), interacting with multimedia objects such as a demo file or images (Figure 9), and backtracking via the ‘History Cabinet’ and the ‘Archive’ tools.

FIG.4. An attached ‘Thesauri & Knowledge Package’ for additional value-adding information
FIG. 5. Locating and checking details of items of interest using a "Time Line" view in InfoSphere Organiser and Object Explorer simultaneously.

FIG. 6. Coordinated-highlighting used in determining term distribution within an article.
FIG. 7. ‘Body & Clone’ and ‘Focus + Context’ view within PROPIE.

FIG. 8. Using ‘Citation Linking’ to browse through related works in Object Explo.
FIG. 9. Interacting with images within article in Object Explorer using ‘Magnifying Lens’ and ‘Bio Lens’ (‘Image Quick View’).

The PROPIE design employed several principles of interface design [47, pp.74-75]. For example, consistent sequences of actions are ensured in similar situations; identical and simple terminology used in menus; and consistency of colours, layout, capitalisation and fonts are employed throughout PROPIE. In general, the researchers also attempted to follow the guidelines proposed by Mullet and Sano [64] of “elegance and simplicity; scale, contrast and proportion; organisation and visual structure; module and program; image, representation and style” in designing the mock-ups for the evaluation. However, in order to incorporate a set of functionality to support some of unique tasks such as in providing context and overview, and multiple representations while allowing users to examine details at the same time, trade-offs of some traditional design principles are inevitable. There is for instance, a need to maintain a multiple workspace environment even as this results in a certain degree of clutter within the environment.

7.2 Data collection techniques

A combination of techniques (in the forms of fixed-response and open-ended questionnaires) and measurement (in the forms of rating and ranking scales, and qualitative feedback) was employed. The dependent variables in the study are divided into four major conditions as shown in Table 2.
Table 2. Dependent variables used for the study.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Operationalized Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rating of tasks/functionality</td>
<td>• Likely level of task difficulty</td>
</tr>
</tbody>
</table>
| 2. Rating of features/tools                    | • Likely level of usefulness  
• Likely frequency of use  
• Preference                                           |
| 3. Perception and Satisfaction with various features/tols | • Overall reaction to features and functionality  
• Conceptual understanding of the various features and functionality  
• Comparing experience with PROPIE to traditional interaction with printed journals and current versions of e-journals  
• Preferred control of the various parts of PROPIE  
• Perception of the overall layout and structure |
| 4. Perception and Satisfaction with the overall PROPIE | • Overall reaction to the environment                                                     |

Tasks, features and tools variables are defined, and their outcome variables are a direct result of the participants’ rankings of the tasks, tools and features. Perception & Satisfaction variables were operationalised by items scored on the post-evaluation questionnaire. Participants completed the post-evaluation questionnaire immediately after their evaluation of PROPIE. Multi-point rating scales (such as Likert Scale of 1 to 5) were employed to get participants’ responses on the various variables in the study. In certain cases, participants were also asked to rank items for their perceived usefulness or preferences.

7.3 Data collection environment

An integrated environment was designed to facilitate the evaluation process - sequencing all the task scenarios, prompting participants through a step-by-step simulation (through guided cues built within the environment at designated points – e.g. pop-up tool-tips), displaying the output in the respective workspaces, and displaying the online evaluation questionnaire at the end of each scenario for users’ ranking and other inputs. Data used in the scenarios was extracted from relevant documents to simulate a realistic working environment.

Control of the evaluation environment was carried out via the ‘PIE Control’ toolbox located at the bottom left-hand corner of the interface (Figure 2). This allows the complete set of mini scenarios to be advanced sequentially. Participants could advance from task to task, reverse to a previous task to for instance, alter or add comments, to reload a particular task, or to skip a task and jump straight into a chosen task at any time.
during and after the evaluation. The ‘PIE Control’ could also be used to display (or hide) the task instructions, and any of the workspaces. It is also used to prompt the evaluation questionnaire. This evaluation questionnaire was implemented (using Microsoft® Visual Basic 5.0) to support the collection of data relating to participants’ ratings and ranking of preferences, and their subjective comments (see Figure 10).

![Diagram of PROPIE interface](image)

FIG.10. Online evaluation questionnaire within PROPIE.

This online questionnaire was linked to a database (using Microsoft® Access97 for Windows) to facilitate data collection. The database was critical in promoting the interactivity of data collection and data analysis.

7.4 Participants profile

All participants in the study were graduate students (a total of 3 Doctoral students and 19 Masters students). The majority of them (13 of 22) were part-time students enrolled in the Masters in Information Studies program at NTU. These students were from a variety of academic and professional background. Three of them were full-time research students within the DIS. Six additional participants (graduate students majoring in the engineering discipline) were invited from National University of Singapore (NUS). All participants had used both printed and e-journals for their studies. These experiences were necessary because PROPIE was designed with the intention to enhance user interaction with e-documents using e-journals as the example. There were slightly more female participants - 54.5% female and 45.5% male. Participants were distributed in the
following age groups: 63.6% were in the 18-29 age group, 27.3% fell into the 30-39 age group and 9.1% were in the 40-49 age group. It should be noted nevertheless, that this is a group consists entirely of graduate students who have had some exposure to e-journals. Any generalisation of the findings beyond this group hence, needs to be done with care.

8.0 Data Collection

A university laboratory within the DIS was the setting for data collection of the evaluation. Materials used in the evaluation included a consent form, briefing notes, tasks instructions for each of the mini scenarios, a participant questionnaire, PROPIE evaluation questionnaire and a post-evaluation questionnaire. A web site containing full versions of these resources can be found in http://islab.sas.ntu.edu.sg:8000/islab/research/chernli.

A pilot study with three volunteers from DIS was conducted to test various details about the investigation procedures. The results of the pilot study provided input for refining the final evaluation and provided an effective test base and framework for the final study. Timings were generated for each activity and used as a basis for planning data collection sessions for the final evaluation.

The data collection was conducted over three sessions (of one and one and half hours each) as at least four and one half hours were optimally needed to complete all the activities from filling in the participant questionnaire to the completion of the post-evaluation questionnaire. Table 3 summarises the main activities involved for each of the sessions. Data for the evaluation were collected over an approximate one-month period.

9.0 Research Findings and Interpretation

A selection of the findings – those we feel have pertinent implications for design is presented. Descriptive highlights and results of the first data collection session are presented first. They are followed by the evaluation results and feedback gathered during the evaluation conducted over the next two data collection sessions. Results are presented in order of category of data. The section proceeds to address a single research question and their corresponding research objective at a time.

Pre-evaluation findings

The feedback received in the participant questionnaire when we asked participants for their opinion on e-journals showed that functionality of an e-journal was of paramount importance to them. Access was of primary concern, such as access to additional information (e.g. through links) and unprintable materials, currency of contents and searching, and navigation features. Generally, the presentation and organisation aspects were given a secondary prominence.

Participants’ perception of the evolution of journals are summarised in Table 4. While almost all of them reported an enthusiasm about e-journals being an interactive
system, it was somewhat surprising to note that a few of them were rather terrified by the idea of changing the emphasis from a single journal issue to that of an article, and to bits of information within the article. Studies by Kling and Covi [42] and Rayward [50] have for instance, articulated how scholars and users alike have long utilised bits of information within a document, for instance, in tracing references in the bibliographies and footnotes, and in using electronic indices and abstracts to facilitate their searches, especially when searching for a particular document, based on clues about the author or title. For most participants, it was probably difficult to imagine the possibilities and likely advantages of the new forms of e-journals supported by various advanced interaction tools.

Table 3. Data collections sessions and their main activities.

<table>
<thead>
<tr>
<th>Session</th>
<th>Main Activities</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 1. Background & Information gathering session | • Introduction to the study  
• Brief overview of PROPIE and the various tools/features incorporated within PROPIE, including demonstration via overhead projector  
• Completion of the blue consent form  
• Completion of the participant questionnaire  
• Participants were briefly informed of the additional data collection sessions | • To inform participants of study’s the objectives and to provide some orientation to the environment (A script was prepared for this purpose in case additional sessions had to be conducted for any unforeseen reasons)  
• Different colors of items and their separation were crucial to help the session go more smoothly. Participants were requested to handle each document only when instructed to do so by the researcher in order to keep everyone together and focused on the instructions at hand. |
| 2. First phase of PROPIE evaluation involving the first 37 task scenarios (T100 – T450) | • (Verbal) Introduction to Session 2  
• PROPIE evaluation started with T100 and ended with T450  
• Participants were briefly informed of the next data collection session (evaluation of the remaining task scenarios) | • The laboratory was prepared for participants by installing the online questionnaire and the corresponding database. Participants were seated in front of a PC and were given a floppy disc each.  
• With the ‘Task Instruction’ in view, the demonstration of the first task was carried out and presented to participants via overhead projector. The objective and steps of the task were described and explained, and upon ensuring that all participants understood the task and the steps, and had had a clear look at the interfaces, participants were prompted to carry out the evaluation of the first task (i.e. T100). This step was repeated until the end of T450.  
• At the end of Session 2, participants were instructed to save their evaluation results into the floppy discs provided. |
3. Second phase of PROPIE evaluation involving the remaining 34 task scenarios (T460 – T770)

- (Verbal) Introduction to Session 3
- PROPIE evaluation commenced with T460 and ended with T770
- Completion of the post-evaluation questionnaire
- The laboratory was again prepared for participants by installing the online questionnaire and responses from the previous session were installed. Floppy discs were distributed.
- At the end of Session 3, participants again were instructed to save their evaluation results into the floppy discs provided.
- Participants were encouraged to share as much of their opinion and perceptions as possible.

In the participant questionnaire, we also asked participants for their opinion on various features – in terms of how significant it was to have the features in e-journals. The measures were averaged. For each item, the lowest possible measure was “1” and the highest “5”. Items rated higher represented a positive “Significant features to have” response, while lower rated items represented a negative “Simply a gimmick” response.

Table 4. Participants’ perception of the evolution of journals.

<table>
<thead>
<tr>
<th>(1 = Excited; 5 = Terrified)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-journals being an interactive system rather than as a document (in a form similar to printed journals)</td>
<td>1.55</td>
<td>0.67</td>
</tr>
<tr>
<td>Changing the emphasis from a journal issue (i.e. serial, collection of articles) to a single journal article</td>
<td>2.73</td>
<td>0.88</td>
</tr>
<tr>
<td>Changing the emphasis from a journal article to bits of information within the article</td>
<td>2.18</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Features participants perceived as most significant (with means between 4.00 and 5.00) to be included in future e-journals were: searching capability across a wide range of journal articles (4.68), searching capability within an article (4.45), ability to temporarily save interested objects for later exploration (4.41), ability to extract and use ‘retrieved information’ as ‘query set’ for a new query/exploration (4.36), full-text index of every article (4.27), ability to interact with information/display to show new relationships, or to discover new information (4.27), direct links to glossary/definition (4.23), ability to interact with multilevel of information objects (4.23), thesauri package to aid searching (4.18), filtering of information in display (4.18), links to comments/annotations by other researchers on selected work (4.18), links to multimedia files (4.18), ability to retrieve similar works by matching images (4.18), ability to directly extract and apply operation on information objects (4.14), ability to make/save comments to a work (4.14), presenting contents in layers/levels (4.09), display (e.g. mapping) of relationships/similarity of selected article to other works (4.05), and the ability to trace one’s search and browse history (4.05).
Given higher priority were searching-related features. Value-adding features such as links to glossary/definition, thesauri, comments/annotations, multimedia files and search/browse history records were also deemed significant.

It was interesting to note that the ability to temporarily save interested objects for later exploration, and the ability to extract and use ‘retrieved information’ as ‘query set’ for further query or exploration had also been highly rated as significant features. This manifested that users often approach a document not with a fixed goal, but often utilise ‘clues’ they encounter during their search and browse process to further refine or expand their searches and navigation. This is consistent with Bates’s proposed ‘berrypicking’ model [29] in illustrating the evolving and interactive search process users engage in, in using online systems. Other studies on user needs such as the ones by Robins [30], Belkin and colleagues [26] and Ingwersen [31] have also emphasised on this importance of recognising this need for online systems to support the iterative and interactive search and navigation processes of users.

Results of the PROPIE evaluation

In the PROPIE evaluation, participants were asked to rate on a scale of 1 to 5 - the Task Difficulty (TD; 1 = Easy; 5 = Very difficult), the Likely (Perceived) Usefulness (LU; 1 = Essential; 5 = Not useful at all) and the Likely Frequency of Use (FU; 1 = All the time; 5 = Never) of the tools and features discussed in each task scenario. Lower-rated items represented a positive perception with the tools/features/interaction while items rated higher represented a negative perception with the tools/features/interaction.

Findings for research objective 1

The first research objective is to determine the various facets of PROPIE in terms of its proposed tools/functionality, and associated features that enhance users’ interaction with e-journals (e-documents). In order to uncover these, descriptive data for dependent variables - Likely level of usefulness of tools/features, Likely frequency of use of tools/features and Preferences of tools/features are analysed. A summarisation of the criterion for the analyses of research objective 1 and the tasks related to each criterion is presented in the Appendix.

(1) Browsing through Collections

Users found it useful to be able to access one’s personal and external collections within one workspace (T100 & T150). As three participants stated:

- #21 (T100): “It's so important to have a common interface that lets me access all external collection regardless of who the publishers are and where the collection resides and so on. I find it very troublesome at current time to have to go to different publisher's websites to get access to their journals.”
• #19 (T150): “It is nice to distinguish one's personal collection from an external collection, and to have one window dedicated for this.”

• #22 (T150): “Checking one's personal collection in the same environment is essential. All systems should allow this type of integration between one's personal collection and the digital collections elsewhere. Makes work much more efficient.”

This is consistent with findings of the Café Jus project [45]. The user survey reported that one of the major demotivating factor in the use of e-journals is in the delays in gaining access and the impediments to moving about within and between journals. Displaying items within the collections ‘by subject/topic’ was most popular among participants (LU $\bar{X} = 1.09$, SD = 0.43). The mean ratings for ‘by author’ and ‘by journal title’ were 2.27 and 2.45 respectively. This might be attributed to the fact that examining collections by these later factors assumed more specific prior knowledge of what was being searched for. Checking a collection by ‘publication date’ was deemed most difficult (LU $\bar{X} = 3.55$, SD = 0.80). Checking details of selected information objects through pop-up labels and document panels received quite a positive feedback from participants, with many also welcoming the idea to utilise two to three pop-ups (T130) simultaneously to view and compare a few items.

It was obvious that quite a number of the participants were confused over the ‘Time Line’ display (T110) – stating that the timeline looked a bit confusing and intimidating (especially for first-time users) and that it was not very intuitive for user to know how to make use for the feature. There was nevertheless, some appreciation of its use in showing the distribution of work, as revealed in their subjective comments.

A number of tasks were designed to ask participants’ for their opinions on the various visualisation techniques introduced within PROPIE to display collections. The ‘Forager’ (T160) and the ‘Map’ (T170) received quite positive ratings. Eight participants also showed their appreciation of the ‘DocTOC’ (T190) in the additional comments provided. They particularly liked the features that helped in identifying the size of the document and the types of objects contained within documents. Participants however, mostly stated their dismay and confusion over the ‘CamTree’ [65] (T200). They found the display to be cluttered especially with a large collection. A few of the participants nevertheless, managed to see some values in this type of visualisation:

• #12 (T200): “3 dimensional is very easy for the user to choose the option. In addition, the cone depicting the concentration is very useful”

• #20 (T200): “Again, seems cluttered at first. Useful for context. Forager is probably easier to use but if collection grows, then CamTree can cover more?”

• #22 (T200): “I think this serves a similar function as the forager with maybe the capability to accommodate more documents but when documents grow, the display may seem cluttered, too. the bottom platform is one added advantage however, telling the concentration of document.”
(2) **Seamless Access to other Information Sources**

Three tasks were designed to assess participants’ view on a seamless access to other information sources such as a thesauri (T140), an attached glossary and definition (T370) and a translation tool (T380). Participants generally welcomed these as value-adding features. A few of the additional comments received demonstrated participants’ appreciation of these features beyond that of the current proposed use (in e-journals):

- **#21 (Task 140):** “Truly innovative. This will also be useful for all other systems - like knowledge management systems, financial systems, personnel systems.”

- **#20 (Task 370):** “Is there a way I can save this definition into a personal notebook for reference in the future?”

- **#21 (Task 370):** “Very nice! Maybe also link to encyclopedia? And other language dictionaries? And maybe link an article to a proceeding collection, year book, link an author to ‘who’s who?’ and so on.”

- **#19 (Task 380):** “Very useful and innovative feature to have. Maybe can include an auditory output to pronounce the translation for the user?”

- **#21 (Task 380):** “Wonderful and convenient. As mentioned in previous comment in task 370, should have more links like links to encyclopedia, link to year book, ‘who’s who’ telephone directory, yellow pages, and so on.”

(3) **Browsing Through Items of Interest**

Participants were introduced to a series of tools and features that helped users to browse through items of interest. The **Object Viewer** (T230) was perceived as useful to get a quick view of a selected object. When combined with the **Structure Viewer/OverViewer** for highlight-directed navigation (T250), the response received was also generally positive. This supports the findings of the study by Dillon, Richardson and McKnight [44] in that a system needs to support a user’s exploration of different sections of a document while providing an overview to a document. Participants were also introduced to the ‘Thumbnail’, ‘Book’ [66] and ‘DocLens’ [23] displays. The LU mean ratings of the displays were 1.45 (SD = 0.67), 2.09 (SD = 0.68) and 2.45 (SD = 0.80) respectively. While they were obviously more familiar with the ‘Thumbnail’ display, many of them in T250 recognised the potential features of the other two displays:

- **#5 (T250):** “Bookmark function is very useful so users can make any marks electronically for later reference.”

- **#20 (T250):** “The coordinated navigation is quite essential. At least user has an option. Anytime I don't want the structure view, I simply close that workspace. It's good to have different display options for the structure and layout. User may have
their own preference. And sometimes, if I just need to look at layout, I will choose thumbnail. But if I want to bookmark pages or sections, I will choose the book format. Doclens is quite innovative but maybe quite difficult to use.”

- #21 (T250): “Normally we only get thumbnails. Good to have other options as well. I especially like the bookmark feature in the book. And to flip pages. Alternative ways to read a document that makes the experience more interesting.”

- #22 (T250): “Important to check the structure or to have an overview of document and to have one workspace dedicated to this is very effective. The display options are very innovative. Apart from the normal thumbnail, book format is especially useful because it allows use to bookmark, and so on. Not sure whether doclens is really useful” though.”

Participants generally welcomed the idea of using (multi-) colour-highlighting to check the distribution of selected objects (T260 & T270). Many of them however, were not sure if the ‘Statistics’ tool (T280 & T290) was something that users would utilise frequently.

Most participants realised that the ‘Find/Search’ mechanism (T300) was already a common feature in today’s many online applications. A few of them suggested ways to enhance this feature for use in PROPIE such as to incorporate more complex search function using Boolean operators and voice input. The ‘Zoom-Magnify’ was generally deemed useful. One participant also envisaged its use for checking images.

(4) Filter/Arrange

Filtering and arrangement (and rearrangement) of information were proposed in PROPIE to help users focus on important details as proposed in Shneiderman’s framework [47]. More than half of participants gave these tools an averaged rating (“3”) in terms of their perceived usefulness. Especially for the ‘Arrange’ tool, many (40.9% of participants) thought it was not a tool that would be used often.

(5) Collaborating

Within the PROPIE, a few tools were proposed to stimulate collaboration amongst users and researchers. The mean LU ratings of the related tasks ranged between 2.18 and 2.45 while the mean FU ratings were between 2.45 and 2.95. A number of suggestions (e.g. a point-grading system in organising the comments and annotations; grouping by topics, dates or author) on improving the display of comments and annotations were put forward. Half of the participants gave an averaged LU rating for ‘Annotation-View’ but more than half of them (63.6%) gave a positive LU rating for ‘Annotation-Add’ indicating the emphasis on adding personal annotations rather than checking others’ notes. Many additional comments received for T450 substantiated this observation. It became obvious that annotation could be thought of as another form of filtering, rather than augmenting the source document. As evident from Marshall’s study of annotation practices [67], users are not adding details so much as extracting only the
pieces of interest. They are eliminating mentally, then physically, the bulk of the
document that is not relevant, while at the same time, recording their own interpretations
and thought.

In T760, participants were introduced to the idea of sharing one’s search/browse
history records as a means of collaboration. Some appreciation of this feature as a means
of exchanging information was reflected in their ratings and the additional comments.

(6) Temporarily Storing Items of Interest

Consistent with the data collected in the participant questionnaire, the idea of
‘Pocket Register’ received quite a positive response from participants, with about 60% of
their ratings distributed over “Essential” and “Very Useful”.

(7) Browsing Through Related Work

The ‘Research Compass’ with its three separate tools (‘Citation Linking’,
‘Document Similarity’ and ‘Document Mapping’) was introduced to participants. The
‘Citation Linking’ (T460) and the ‘Document Mapping’ (T560) was received positively,
both with an averaged LU rating of 2.14. The ‘Document Similarity’ (T520) only
received an averaged rating of 3.05 (SD = 0.72). Many found the visualisation in the
latter too complicated for first-time users although some appreciation of its use as a
‘research compass’ was noted. When asked for the preferred number of shapes (or
colours) to visualise information (T520 & T522), the results were consistent with many
existing findings, such as those upheld by Shneiderman [47, p. 399] - that the use of
colours or shapes in a single alphanumeric display should be limited to four (at least, for
novices). Participants showed they were most comfortable with 3-4 shapes or colours in
use.

The ranking preference for display of items in ‘Document Mapping’ (T560) was
consistent with that reported earlier in T100. Display ‘by subject/topic’ was most
favoured.

T710 to T740 introduced participants to a tool that helps in updating users to
recent related works and its various display options. Participants generally demonstrated
an appreciation of the usefulness of the ‘Alerting/Updating’ tool. Some of their
responses were:

- #18 (Task 710) – “Updating is essential. people reads journal to update oneself,
right?”

- #19 (Task 710) – “Useful feature to help stay alert of new developments in a field.
Can system include some kind of indication to let user know if there has been any
new update, and if yes, how much, etc?”

- #20 (Task 710) – “I’ll probably update myself once a month. This tool helps.”
• #20 (Task 730) – “Timeline is a good way to show the recent updates and the amount of recent work. I can quite easily tell when work and how much was done in what area.”

The mean ratings for participants’ preference of display showed that many still prefer the familiar ‘list’ view. However, a few of them exhibited an awareness that a ‘list’ might not be the best option at all times especially when the items/collections grew.

(8) Interacting with Multimedia Objects

Participants reacted positively to the multimedia-based features. The mean LU ratings for these tools and their features ranged between 1.91 and 2.50. Checking out a demo in Object Viewer while maintaining the context of the original document (T570) proved to be popular. Although most participants were unfamiliar with the features proposed in T580 (‘live test’) and T590 (interactive data sets), most of them received the ideas positively, foreseeing their potential as value-adding features. Many also suggested alternate means to further enhance the features in ‘Image Quick View’, such as to have more flexible zooming mechanism. Almost all participants also welcomed the ability to arrange the images by ‘topic/subject’. Only about half thought, that arrangement by ‘colour’ or ‘shape/geometry’ was useful.

(9) Backtracking

The backtracking features were mainly received positively. Suggestions to improve and enhance ‘History Cabinet’ and its ‘Archive’ included those of allowing users to undo/remove unwanted/out-of-date history records, ensuring easy access to the tools (e.g. iconic design, easy menu selection) and providing more user-friendly interface and interaction for these tools.

For the displays in ‘History Cabinet’, participants again showed a preference for the more familiar and ‘easier-to-use’ list view. Appreciation of other display options was reflected nevertheless, in some of their additional comments. For instance:

• #19 (Task 660) – “Calendar is better than a list. At least, there's a kind of categorization of events.”

• #20 (Task 670) – “Timeline is good. Not only it tells me when the operation was, but also the concentration of activities. Very nice.”

• #18 (Task 680) – “Context is good but using perspective wall may not be easy.”

• #19 (Task 690) – “Graphical view is very innovative. But user will need to learn how to use this feature. Can be very useful because it visualises the history event.”

• #20 (Task 690) – “The graphics can be very useful indication of what operations I have carried out. Also a easy reminder of what documents I have used. Sometimes
looking at the document name doesn't help refresh my memory but this graphical view does. Great.”

- #20 (Task 700) – “I will choose this display if I want to know the size of documents I have used and to retrieve specifically images or audio files.”

Findings for research objective 2

The second research objective is to determine the various facets of PROPIE in terms of its proposed concepts and interactions that enhance users’ interaction with e-journals (e-documents). Descriptive data for dependent variables Likely level of usefulness of proposed concepts and interactions, Likely frequency of use of proposed concepts and interactions, and Preferences of proposed concepts and interactions are analysed. To examine participants’ feedback on the various proposed concepts and interactions, the results are scrutinised by the following activities (see Appendix).

(1) Extracting Items of Interest

The ‘drag & drop’ mechanism was positively rated by majority of the participants. 86.4% of participants thought it was the most intuitive method to move objects within the environment, following by ‘highlight to select object, right click and then select move option from a pop-up menu’. Three participants indicated that more than one option however, might be necessary to suit different user needs and experience.

(2) ‘Focus + Context’ Viewing and Exploration

T340 and T350 introduced participants to the ‘body & clone’ and ‘multi-clone’ analogies. In T340, three of the participants had a preconception of the ‘multi-clone’ concept before they were actually introduced to the concept (in T350) – demonstrating a learned understanding of the analogy. They were able to visualise the various use and benefits of the proposed analogies:

- #19 (Task 340): “I like this 'body & clone' concept. Can be very useful for many reasons. For example, I can gather a few clones from a few articles. Then decide what to do with them.

- #21 (Task 340): “Very nice. So, I can apply different tools to the same 'clone'? I like the idea of a clone and maybe clones ... very futuristic and imposes all kinds of possibilities! Maybe I can create a few clones of the same paper in the future and use them for different projects?”,

- #22 (Task 340): “I think body & clone is not fanciful but has great values actually. For example, I can take a few links in the document that don't appear in the same page and place them all in object explorer first. Then I can check out each one by one without going from page to page to find them again.”
(3) Controlling the Amount of Information Displayed

Most participants favoured the idea to be allowed some kind of control over the proposed environment. The type of control desired was later examined in the post-evaluation questionnaire. It was obvious that participants also preferred having details presented by some control (e.g. via layers/levels) (Table 5). Many went on to suggesting breaking down the ‘layers/levels’ into even smaller sections so that user could choose as precise as they could on the details they wished to check out. A focus group conducted for the NSF/DARPA/NASA Digital Library Initiatives (DLI) project at the University of Illinois [11] reported a similar response from the faculty members who took part in the study. The process of stepping from “a little information” to “more information” (e.g. from titles and authors, to introductions and section headings, to full-text) was deemed crucial to their review of documents. According to study participants of this project, it would be important for digital systems to support this process, and perhaps, to make it more customisable to individual user needs.

<table>
<thead>
<tr>
<th>Task 360</th>
<th>Task 390</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Difficulty (TD)</td>
<td>1.55</td>
</tr>
<tr>
<td>Likely Level of Usefulness (LU)</td>
<td>1.91</td>
</tr>
<tr>
<td>Likely Frequency of Use (FU)</td>
<td>2.09</td>
</tr>
</tbody>
</table>

Findings for research objective 3

The third research objective is to elicit descriptive information to determine the various facets of PROPIE which inhibit users’ satisfaction with the proposed environment in terms of interaction, tools/functionality, and features of tools. Participants rated their perception and satisfaction with the overall features/functionality and presentation in the post-evaluation questionnaire on a scale of 1 to 5 with the anchors Strongly agree (1) and Strongly disagree (5).

Participants’ overall judgement of the environment was quite positive. The various functions within PROPIE were perceived as capable of enhancing interaction with journals and more than 86% of them acknowledged the possibility of using PROPIE to enhance one’s searching and browsing tasks. The distribution of the ratings revealed that participants had more problems understanding the layout and structure, and display of PROPIE, rather than with the tools and functionality available. The underlying reason for this may be due to the fact that participants were not familiar with having to work simultaneously with various workspaces and information objects.

Table 6 shows that almost all participants (90%) perceived the use of PROPIE for interacting with journals as being ‘much more in control’ and ‘somewhat more in control’. In comparison with printed and currently available online journals, PROPIE provided features that supported enhanced interactions with journals. Particularly ranked at top as important features were - integration of the environment with various
searching/exploration tools, collaborating with other researchers through for instance, digital annotations and comments, searching and navigation on information objects to reveal additional information (e.g. metadata), interaction with information objects down to the level of a single word, image, equation, etc., temporarily saving of information objects for further exploration while user returns to original task, backtracking, a visually-rich interaction environment – with co-ordination amongst the various workspaces, integration of querying, navigation and visualisation in a single environment and visualisation of search output.

<table>
<thead>
<tr>
<th></th>
<th>Much more in control</th>
<th>Somewhat more in control</th>
<th>About the same</th>
<th>Somewhat less in control</th>
<th>Much less in control</th>
<th>Mean Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currently available e-journals</td>
<td>12 (54.6%)</td>
<td>8 (36.4%)</td>
<td>1 (4.5%)</td>
<td>1 (4.5%)</td>
<td>0 (0.0%)</td>
<td>1.59</td>
</tr>
<tr>
<td>Printed journals</td>
<td>14 (63.6%)</td>
<td>6 (27.3%)</td>
<td>0 (0.0%)</td>
<td>2 (9.1%)</td>
<td>0 (0.0%)</td>
<td>1.55</td>
</tr>
</tbody>
</table>

An interesting observation was that ‘visualisation of search output’ was amongst those most positively rated even though participants had earlier experienced some difficulties with some of the visualisation techniques (e.g. ‘CamTree’). An earlier speculation of some participants facing problems with working simultaneously with multiple workspaces and information objects was substantiated in that a few of the participants did perceive it to be ‘somewhat more cumbersome’ to have to work with various workspaces and objects, and in applying the ‘body & clone’ analogy.

Participants welcomed some kind of control over the overall interaction environment (as earlier reflected in T220). None of them thought that the workspaces should be fixed in a particular mode or position and about 91% of them stated that users should be allowed to minimise or enlarge any workspaces, and to hide or display any of such workspaces according to various needs and preferences. All participants perceived a 17” monitor as the minimum requirement for an environment such as PROPIE to ensure visual clarity throughout the interaction environment for normal vision.

Findings for research objective 4

The fourth research objective is to provide important input for the continued development of an environment/ graphical user interface of future e-journals (e-documents).

Five participants (33.3%) expected e-journals in the future to be easier to use and to provide end-users with more control over the environment and functionality. One participant simply stated “multi-media e-journal” – suggesting the trend for the next generation of e-journals to be mostly multimedia-based. An interesting and encouraging observation was that 46.7% (7 participants) of the expectations and enthusiasms asserted
were associated with PROPIE in a positive manner. The overall tone implied an optimistic response to the many possibilities presented in PROPIE.

81.8% of participants indicated aspects of PROPIE that are found to be particularly useful. Organisation and visualisation (e.g. mapping) of related work was most popular amongst participants (listed by 36.4% of them). Visualisation features were also frequently mentioned (listed by 31.8% of participants). Other tools and features cited were history records, context view, annotations/comments, pop-up windows (information), the Pocket Register and zooming. Two participants mentioned the ability to access both personal and external collections, and one of these responses also stated the multiple workspaces as a positive feature.

Areas or aspects of PROPIE that was particularly found confusing or difficult to understand, or annoying was also elicited from the participants. This was aimed at identifying participants’ feeling of disorientation or ‘getting lost’. 77.3% of them responded. Many of these were a direct result of having too many various tools and features within PROPIE (listed by 41.2% of respondents). As one participant indicated: “Too feature rich at times. It can be confusing...” and suggested some kind of standardisation of the available features. A second problem that was mentioned related to the understanding of some visualisation features – a few of them found visualisation features such as the ‘Map’ and ‘CamTree’ confusing especially at first glance. A third category of problems related to having to work with too many workspaces and cluttered screen.

Participants were also asked to describe the PROPIE informally to a friend or colleague and to write an informal description of their account. This was geared toward discovering if participants possessed a conceptual understanding of the purpose and design of PROPIE. A content analysis was conducted on this question that generated 81.8% responses. A list of keywords and terms was used as a template for determining participants’ understanding. These included – ‘integrated environment’, ‘collection of tools and features’ and ‘enhanced interaction with e-journals/e-documents’. These were compared against participants’ responses. Overall, more than three-quarters of participants (77.3%) demonstrated an understanding of the basic purpose of PROPIE as an environment for enhanced integrated access to e-journals (e-documents). Many of them went on to describe and elaborate on the various tools and features available. One participant used a metaphorical analogy “under one roof” to describe the availability of many tools and features. 72.7% of responses contained language such as the environment was “useful” or “easy” (to use). 22.2% of the respondents specifically stated their enthusiasm for a working environment such as PROPIE to be implemented in the near future for e-journals. One of these respondents also suggested the use of the environment for other e-documents such as for online newspapers. PROPIE was shown to be a promising environment for interacting with e-journals as five participants proceeded to compare it favourably to current versions of journals.
10.0 Discussion

As a result of the empirical evaluation, valuable insights have been gained in the designing of an integrated environment to support a new generation of value-added e-documents. General implications are discussed here in the context of the five interaction properties presented earlier in Table 1.

The integration of workspaces through the user’s personal workspaces (Object Viewer, Structure Viewer/Overviewer and Object Explorer) and the broader information world (InfoSphere Organiser) is generally perceived as an important feature that enables a uniform paradigm for accessing one’s own workspace and the information world at large. This integration also facilitates the task of consolidating one’s intermediate and final information searching results into the initial task.

Throughout all the workspaces, user-controlled malleability enables one to perform direct manipulation on information objects at different levels. Users can rearrange, filter and zoom in on selected objects for more details when required and desired, using for example, the ‘Arrange’, ‘Filter’ and ‘Zoom’ tools in the Structure Viewer/Overviewer. They can also explore, navigate and perform queries almost simultaneously, and intuitively select, drag and drop objects throughout the various workspaces.

Visual sovereignty is ensured throughout PROPIE by providing users with contextualised views during their information gathering and analysis tasks. How an item fits within a collection set and within the broader information world is indicated to the users through a number of tools and features - for instance, through the ‘Time Line’, ‘Map’, ‘Forager’ and ‘CamTree’ displays, the co-ordinated and highlight-directed navigation between Object Viewer and Structure Viewer/Overviewer, the use of the various tools in ‘Research Compass’ to browse through related work, and through the ‘Alerting/Updating’ tool in Object Explorer. Users are also able to backtrack their browse and search history records through the given visual representations of these records in the ‘History Cabinet’ (and the ‘Archive’) and the ‘Pocket Register’. Users have also found the ‘focus + context’ viewing supported by the ‘body & clone’ and ‘multi-clone’ analogies useful.

To support a variety of needs and preferences, users are given a multiple representation of information objects. PROPIE’s interface allows direct manipulation on the various aspects of the representation and view, and their organisation. Within InfoSphere Organiser, Object Viewer, Structure Viewer/Overviewer, and within the ‘Research Compass’, the ‘History Cabinet’ and the ‘Alerting/Updating’ tools for instance, users can choose a view of interest from multiple display and organisation options according to the task(s) at hand and their needs.

PROPIE provides users with an integrated suite of appropriate interactive tools for querying, navigation, organising and authoring information. Throughout the environment, users can for instance, specify a query against a set of objects, navigate
with aids of visual clues about where items are, and obtain specific information by a zoom mechanism. The evaluation findings also show that users welcome the ability to make and save digital comments and annotations, and attach these to an object (e.g. an image, a sentence or an article). The users’ response also show that seamless access to other information sources such as to a thesauri, an attached glossary/definition and a translation tool are greatly desired as value-adding features to be included in future e-documents. The ability to interact with for instance, a demo file, interactive data sets and images are also found enticing.

In summary, we find the coalition of characteristics arrived at in PROPIE to be overall abounding – propagating a suite of possible rich interactions within one single UI environment to enhance user interaction with e-journals, and to add value to these e-documents.

Limitations of Study

A number of limitations are apparent in this study as a result of the assumptions made in the design of PROPIE and the chosen evaluation techniques. These are described briefly below.

The choice of using e-journals as a form of e-documents in this study has somewhat implied that the results generated will not be totally generalisable to all other online documents. Nonetheless, a selection of the more general findings related to the assumptions about PROPIE as an environment for interaction with e-documents may be useful for a general discussion.

The sample size of the study is small (22 participants). Ideally, it should be increased to better represent the user population, thereby allowing population statistics to be applied, which will in turn yield more conclusive findings. The current sample nevertheless, consists of highly motivated respondents who have contributed a fairly substantial set of data that were used for analysis and the derivation of findings subsequently. As an indicator, an average of 70% of the respondents provided qualitative comments on a per-task basis (i.e. a total of more than 1,000 comments were accumulated during the data collection process). The prolonged hours (approximately 5 to 6 hours) spent per participant in the data collection process somehow indicate that the sample size cannot be substantially increased due to practical reasons. We also acknowledge the fact that all participants in this study are graduate students and hence, generalisations of the findings beyond this group of representative users need to be done with care.

It is also apparent that the simulated mock-up used in the evaluation is obviously inferior to that of a working prototype. Such a prototype will no doubt allow participants to interact in a more ‘real-life’ manner on a set of real data, which will in turn, likely to return a set of superior evaluation results. Reasons of feasibility and implementation however, made this impractical.
We also have not carried out a thorough feasibility and cost evaluation, or attempted to look at the legal and practical issues involved in making what has been proposed in this study a realism. This is so as the overall objective at this stage of study is to address the research questions outlined earlier. Nevertheless, such investigation and estimates will obviously be essential and will need to be looked into in future. Some of these issues have been investigated in some earlier works. For instance, some have looked into the social, economic and political considerations [15, 41, 42, 68, 69, 70], some others have examined the cost and implementation issues [71] concerning electronic publishing, and the distribution and use of e-documents.

11.0 Conclusions

In this study, we have taken a prodigious leap to examine functionality and features required and desirable in a new generation of enhanced e-documents. We believe that it is simply a matter of time when reading only printed journals (documents) is no longer sufficient since users will be missing so much of the enhanced contents that electronic makes possible if they do so. Market forces and competition will also propel changes to happen in the near future so that user-centric e-document systems satisfying real user needs will ultimately evolve.

PROPIE has been designed to investigate how various tools and features can be integrated into one single UI environment, where users are able to apply different tools and features flexibly, and in a complimentary manner so as to facilitate and enhance their various needs in interacting with e-journals.

Through the empirical evaluation conducted on PROPIE, we believe that we have made substantial progress toward that goal. Participants in the study were able to perceive the usefulness of the various tools and features incorporated in PROPIE, and to appreciate their potential in serving different purposes and needs. Based on the findings, we further believe that our success with PROPIE can be improved with some modification to the UI, increased user training or user experience with the environment.

As part of our future work, we intend to incorporate an online help facility within PROPIE to improve the screen designs further by for instance, examining alternative means to present the tools and features, such as using iconic menus, pop-up menus instead of pull-down menus, toolbars or palettes and alpha-sliders. We have also targeted a larger pool of participants to participate in our next stage of study. Using this subsequent set of accumulated data, we expect to carry out further detailed and systematic investigations to explore possible relationships of various variables. Particularly, we intend to verify empirically - whether user individual characteristics (e.g. gender, age, spatial ability) and experiences (e.g. computer and journal usage) have an effect on how participants perceive the various aspects of PROPIE, especially on features that are visualisation-based, that demand certain degree of spatial orientations and scanning ability.
We are also planning to investigate a potential alternative approach for the environment – using a vast, border-less work surface whereby all information objects reside on this surface (including the user’s current work, personal collections and representation of the external world). To interact with the objects, a virtually infinite pan and zoom capability is applied. This single, border-less workspace would similarly assume a synergy of query, navigation and visualisation. Whether users would prefer this to the multiple-workspace environment (such as PROPIE), or if users would find it too confusing or visually-demanding to comprehend a screen filled with vast amounts of miniature text and images without any organisation, would prove useful in providing further understanding of how digital interaction will evolve in the future.

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Appendix  
Research objectives - the criterion for evaluation and the related task scenarios.

<table>
<thead>
<tr>
<th>Research Objective</th>
<th>Criterion for Evaluation</th>
<th>Related Task Scenario(s)</th>
</tr>
</thead>
</table>
| #1 To determine the various facets of PROPIE in terms of its proposed (i) tools/functionality and (ii) associated features that enhance user’s interaction with e-journals. | (1) Browsing through collections | • T100 - Checking external collection in InfoSphere Organiser  
• T110 - Checking works on a particular subject in the external collection through TimeLine display  
• T120 - Checking details of selected information objects through pop-up labels and document panels  
• T130 - Keeping more than one document panel in display using different colours to distinguish  
• T150 - Checking Personal Collections in InfoSphere Organiser  
• T160 - Viewing Personal Collections using the Forager View  
• T170 - Viewing Personal Collections using the Map View and checking details through pop-up labels and panels  
• T190 - Viewing Personal Collection through DocTOC display  
• T200 - Viewing Personal Collection through CamTree display & preference for the display of items within the collections in InfoSphere Organiser |
| | (2) Seamless access to other information sources | • T140 - Thesauri & Knowledge package in Object Explorer  
• T370 - ‘Glossary & Definition Lens’ in Object Explorer  
• T380 - ‘Translation’ in Object Explorer |
| | (3) Browsing through items of interest | • T230 - Using Object Viewer workspace to get a quick view of selected object using scrolling mechanism and choice of what section(s) to display  
• T250 - Highlight-directed navigation between Object Viewer and Structure Viewer to assess document length, structure and layout with multiple display options  
• T260 - Using colour-highlighting/directed-navigation to check distribution of selected a selected object  
• T270 – Using colour-highlighting to check distribution of more than one object  
• T280 – Using ‘Statistics’ to check distribution of selected object (eg. term/phrase)  
• T290 – Using ‘Statistics’ to check distribution of more than one selected object  
• T300 - Using ‘Find/Search’ mechanism to locate specific information/section  
• T330 - Using ‘Zoom - Magnify’ in Structure Viewer to examine details of object |
| | (4) Filter/ Arrange | • T310 - Using ‘Filter’ in Structure Viewer to (temporarily/permanently) filter unnecessary information  
• T320 - Using ‘Arrange’ in Structure Viewer |
| | (5) Collaborating | • T400 - Using ‘Comments – View’ in Object Explorer to learn from others  
• T410 - Searching in ‘Comments-View’ by author  
• T420 - Display options (eg. “Display All”; “Display Only Accessible Comments”) in ‘Comments-View’  
• T430 - Using ‘Annotation-View’ in Object Explorer to learn from others  
• T450 - Using ‘Annotation-Add’  
• T760 - Sending history records in History Cabinet to others for discussion/learning purposes |
| | (6) Temporarily storing items of interest | • T440 - Using ‘Pocket Register’ to temporarily store objects of interest for later exploration |
### Browsing through related works

- T460 - Examining related work through ‘Research Compass – Citation Linking’ in Object Explorer
- T470 - Various display options (eg. by author, by publication date) in Citation Linking
- T480 – Performing keyword search to locate specific citation(s) in Citation Linking
- T490 - Locating works of specific author(s) in Citation Linking
- T500 - Checking details of related work in Citation Linking through pop-up labels and panels
- T510 - Checking details of related works through more than one pop-up panel in Citation Linking
- T520 - Examining related works through ‘Research Compass – Document Similarity’
- T522 - Examining related works through ‘Research Compass – Document Similarity’ (use of colors/ shapes)
- T530 - Examining related works through ‘Research Compass – Document Similarity’ using pop-up labels and panels
- T540 - Locating works by specific author(s) in Document Similarity
- T550 - Changing criterion in Document Similarity to retrieve different sets of related work
- T560 - Examining related works through ‘Document Mapping’ using pop-up labels and panels
- T710 - Examining new items through ‘Alerting/Updating’ in Object Explorer
- T720 - Examining new items through ‘Alerting/Updating’ using ‘List view’
- T730 - Examining new items through ‘Alerting/Updating’ using ‘Timeline view’
- T740 - Examining new items through ‘Alerting/Updating’ using ‘Map view’

### Interacting with multimedia objects

- T570 - Viewing interactive demo in Object Explorer
- T580 - Carrying out a ‘Live test’ to interactive graphs/equations by allowing user to enter their own sets of data
- T590 – Interacting with parts of author’s data and observations through ‘Data Sets’
- T600 - Having a quick view of all images/diagrams within an article through ‘Image Quick View’ and using ‘Magnifying lens’ to check details
- T612 – Using ‘BioLens’ in ‘Image Quick View’ to get further explanation/details of images/diagrams (re-arrangement of images)

### Backtracking

- T180 - Checking use/history records on selected article.
- T240 - ‘Small panel’ in Object Viewer to display use/history records of selected object.
- T620 - Checking objects temporarily saved in Pocket Register.
- T630 - Saving items stored in Pocket Register to Personal Collection.
- T640 - Checking recent search history records in ‘History Cabinet’ to trace interested data/information.
- T650 - Checking recent search history records in ‘History Cabinet’ using ‘List view’.
- T660 - Checking recent search history records in ‘History Cabinet’ using ‘Calendar view’.
- T670 - Checking recent search history records in ‘History Cabinet’ using ‘Timeline view’.
- T680 - Checking recent search history records in ‘History Cabinet’ using ‘Perspective Wall view’.
- T690 - Checking recent search history records in ‘History Cabinet’ using ‘Graph History view’.
- T700 - Checking recent search history records in ‘History Cabinet’ using ‘DocTOC view’ & preference for the display of items within the collections in History Cabinet.
- T750 - Saving search and navigation processes into History Cabinet for future reference.
- T770 - Viewing previously saved history records in Archive (in History Cabinet)
<table>
<thead>
<tr>
<th>Research Objective</th>
<th>Criterion for Evaluation</th>
<th>Related Task Scenario(s)</th>
</tr>
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<tbody>
<tr>
<td>#2 To determine the various facets of PROPIE in terms of its proposed concepts and interactions that enhance user’s interaction with e-journals</td>
<td>(1) Extracting items of interest</td>
<td>• T210 - Extracting objects of interest using the ‘drag &amp; drop’ mechanism</td>
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</tbody>
</table>
| | (2) ‘Focus + Context’ viewing and exploration | • T340 - Using ‘Body & Clone’ analogy to get a ‘focus + context’ view in examining selected object  
• T350 - Using ‘Multi-Clone’ analogy to get a ‘focus + context’ view of selected objects – to eg. compare results of different queries performed on the same object/ same query performed on different objects |
| | (3) Controlling the amount of information displayed | • T220 - Controlling PROPIE workspaces.  
• T360 - Presenting details by layers/levels.  
• T362 - Presenting details by layers/levels (use of colors to distinguish layers/levels).  
• T390 - Drag & drop selected object into Object Explorer and get full content view directly. |