Small Screen Access to Digital Libraries

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ABSTRACT
This paper looks at the possibilities of taking existing digital library technology and using it for educating those who do not normally have access to the Internet. Our solution is based on cellular telephone technology and we investigate the feasibility of a system for accessing the Greenstone digital library using WAP handsets.

Keywords
Digital libraries, digital divide, mobile interaction

INTRODUCTION
Africa is a continent of many diverse cultures and talents, and has the potential to impact the world both culturally and economically in a highly positive way – the "African Renaissance." However, as we march further and further into the 21st century it would seem that Africa as a whole is falling further and further behind in terms of both economic and cultural development. The high mortality rate, rampant spread of AIDS and extensive famine are but some of the problems holding back Africa from realizing its full potential. While these problems may seem diverse and unrelated, a common chord runs through each – lack of information.

As the developed world now moves into the "Information Age", most of Africa is still waiting for the industrial age. However, those in the developing world are looking to leapfrog the industrialization stage and join the information age directly. By making information ubiquitous and freely available, the Internet should make it possible for developing nations to compete globally on a level playing field.

However, the current difficulties in accessing the Internet from developing countries means that, unless direct action is taken, the information age may also pass us by. Within Africa, we do not have the luxury of providing Internet access as an edutainment diversion – we need to focus on how to use the Internet to empower the greatest number of people in the most effective way. To that end, we have embarked on a project to use existing Internet technologies and telecommunications infrastructure to make the Web an effective tool for upliftment within South Africa.

If we are going to make useful information available to a wide group of people, then there are a number of key issues that need to be addressed:

- **Content**: Although it contains a lot of useful information, the Web is currently clogged with irrelevant and unhelpful information. If the Web is to become a useful tool, then some way needs to be found to filter out that material which is not useful and better catalogue the material that could be useful
- **Distribution**: In a country as large as South Africa, there are many problems in providing land based telephone lines. If more people are going to access the internet, then it is unlikely that land based telecommunications are going to provide the answer
- **Access**: Typically, a personal computer is required to access the internet. Expensive, bulky, fragile and requiring large amounts of power, the personal computer does not seem like an ideal candidate for providing universal access in South Africa.

Providing Content
To be an effective tool, not an entertainment medium, the information on the Web needs to be edited, categorized and stored in a concise and easily searchable way. Although this may seem like a pipe dream, it describes exactly the goal of digital libraries. We have been working with the New Zealand digital library group who have, in turn, been working with the United Nations and UNESCO to develop digital library collections for the developing world using their Greenstone digital library software[5]. Already they have developed collections such as the "Human Development Library", "Food & Nutrition Library" and the "Medical and Health Library." These libraries, and many others, contain information which is highly valuable to any developing country. In [14], Witten et al provide a full list of all the collections available on Greenstone for developing countries (some 3590 publications). The article also points out the cost benefits to developing countries of delivering information in this way – for example, the paper version of the Human Development Library alone contains some 1230 publications, weighing 340kg and costing $20000 to print!

This information, however, is only effective if it is made accessible to those who need it most.

To improve access, this software (called Greenstone) runs on Linux and all Windows versions (including 3.1). It is freely downloadable from the Web or can be obtained on CD-ROM from the United Nations. The UN also have pre-packaged versions which ship with a particular collection, such as the "Human Development Library." (Figure 1 shows some of these CD covers).

Figure 1 – Two of the humanitarian collections made available on a Greenstone CD.

Greenstone works by taking a directory of electronic documents (most formats, including PDF and Word are supported) and collate, compress and index these into a coherent collection. The software also comes with an interface to allow users to create their own collections which can be burnt to CD or used with a Web server to make the collection available as HTML documents. Whilst this represents a great step forward in distribution of information, it still relies on the recipient having access to a PC on the internet, or a PC with a CD-ROM drive. Within the African context, this still remains a huge hurdle.

Distribution & Access

If we are to make information available to those who need it most, then we need to consider infrastructure within our own country and continent. One thing which is striking about telecommunications infrastructure in South Africa is the quality of the cellular services. Currently over 9 million South Africans have cellular handsets, more than have land lines or personal computers. With the introduction of new services (GPRS) and service providers, this number is set to grow. Furthermore, the new services will be based on packet-switched technology, making mobile access a financially more appealing proposition than current circuit-switched technologies. Therefore, we believe that mobile internet access will also become more important in the development of the internet in South Africa. (In Japan, for example, the iMode mobile internet access service has 23 million subscribers, whilst PC based access to the internet is around 8 million.[11])

So if we are to succeed in our goal of making the Greenstone information available to the greatest number of people, then cellular handsets would seem like the best way to proceed.

Some researchers are working in the area of developing dedicated mobile terminals for library access[10]. Whilst this research provides an interesting discussion of potential future technologies, it has little direct impact on our work. This, and solutions such as those proposed in [1] are based on high resolution, full color A4 size tablet computers – clearly beyond the means of our target audience. We need to find ways to fully exploit existing technology (like WAP); an area of research which has been largely ignored in mobile computing.

HTML and WML

If we are to marry Greenstone technology and digital handset technology, then the biggest hurdle to overcome is in translating the HTML from Greenstone into WML (Wireless Markup Language) for the wireless device. As stated in the previous section, we cannot utilize much of the user interface research in mobile digital library access, as this relies on new technologies and new computer designs. The alternative is to look at technologies for creating WML content from HTML, and assess the effectiveness and usability of the output from these systems.

Many such systems exist already (e.g. IBM's Websphere[7]), but the results of the translation suffer a number of problems.

- **Technology**: Many web pages incorporate Java Applets, Flash animation or video clips. No translation technique can produce an equivalent in WML – the technology will simply not support it. Even relatively standard HTML, such as nested tables, has no direct equivalent in WML.
- **Design Intention**: Automatic translators work on the source HTML, but have no idea of the designer's overall intention for the purpose of that page, or how that page fits in to the wider purpose of the site. Even using the semantic tags such as <h1> provide little insight into the designer's intention.

From our investigations into these systems, we can conclude that no existing system will allow us to translate the contents of the digital library into a form which can be easily used on a WAP device.

Design Solutions

The research question then posed is, what is the most effective way to replicate the interaction with Greenstone, or any digital library, using a WML interface? There are two levels of interaction we need to consider to effectively solve this problem:

- **Task level**: The task of retrieving documents from a library has several stages – searching, comparing, reading etc. – which need to be understood to build an effective interaction. As we shall see, retrieving information from Greenstone has five separate stages.
- **Device level**: Having identified the various stages in the interaction, work needs to be done in designing the most effective way to support each stage using the available technology.

Interaction analysis

Analyzing any single interaction with collection-orientated digital libraries, such as Greenstone or the ACM digital library[1], shows that there are similarities in the interaction. We have concluded that interaction with this type of library must include the following stages:

- **Collection** selection: Choosing the part of the library in which you wish to search for your information.
- **Directed searching**: Support must be given for users to enter keywords and retrieve documents containing those words.
- **Browsing**: Some users do not (or cannot) specify specific terms, but would rather browse through the collections hoping to chance upon interesting information.
- **Review**: Having found information, the system should support the reading of that information.

Within the Greenstone system, all four of the above activities are supported. There are, in fact, five separate phases of interaction with Greenstone, which we need to replicate if our system is to succeed. These five phases are shown in Figure 2 at the end of this document. As indicated, using the Greenstone system in the example screen shots, the five phases can be chronologically numbered and named as follows:

1. Connection Phase
2. Collection Selection Phase
3. Browse Method Selection Phase
4. Browse Phase
5. Article View Phase

Each of these phases is represented by a dynamically created HTML page. See the following box for an example interaction

Box 1 – Example Greenstone Interaction

The Connection phase process generates the HTML Welcome Page, which displays the collections available for browsing.

After selecting the desired collection (say Food & Nutrition Library), the second phase (Collection Selection) generates the required HTML page for that collection (the Collection Page) offering information about the collection as well as different methods of accessing the collection e.g. by searching, or browsing by titles, subjects, authors, or organizations.

Having selected a method to browse (let's say, by titles), the Browse Method Selection phase generates the required page (a Collection Browse Page) offering an index of (in this case), alphabetic groups A - G, H - Q, R - Z.

After selecting the desired option, the fourth phase (Browse phase), generates the page so the user is ready to browse the actual books in that directory (the Collection Browse Results Page).

The interaction ends with the selection of the desired book in the provided results, thus entering the fifth phase (Article View) where ultimately the data is displayed within an HTML Collection Article Page.

Design Architecture

Having identified the key phases in the interaction with a digital library, it was necessary to create an architecture which would support this interaction using a mobile device rather than the usual desktop Web browser.

Following the best practice of other researchers in this area [11], our mobile solution is driven by a proxy server architecture where the mobile device's web browser communicates with an Apache Web server operating an Apache Tomcat environment for Java Servlet transactions.

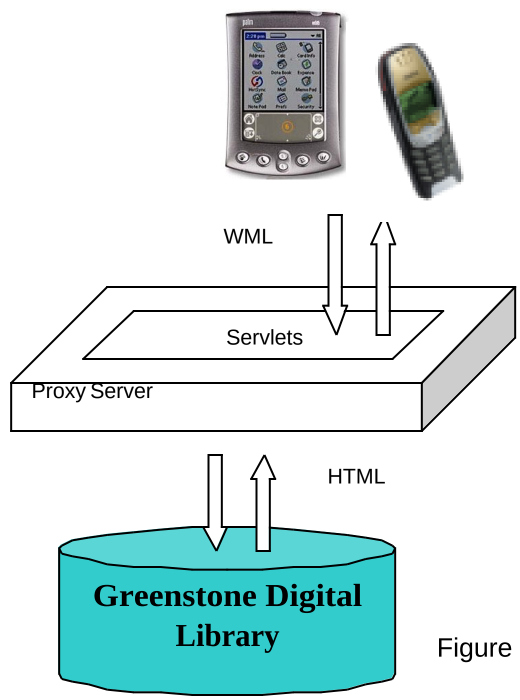


Figure 3

Each of the 5 phases has an associated servlet that performs three main roles:

- **Request Handling**: Extracts the important user input from the WML, generates the correct request, and then requests HTML from Greenstone for the generated request
- **Translation**: This involves converting the HTML information provided from Greenstone into WML. This is a complex process and, as we shall see in the next section, requires an interim translation to XML.
- **Response Handling**: This simply involves extracting the generated WML file from the translation stage and returning it to the mobile device.

Translation

We have already seen that automatic translation between generic HTML and WML is problematic. Building such a translator for Greenstone HTML is much easier as we know the author's intention and we know that the query results contain only HTML – there is no Flash or other multimedia content other than sound and static images.

However, rather than write an HTML – WML translator, we opted to create an HTML – XML – WML translator.

We achieved this by having two generators, one for XML and the other for WML.

The XML generator works by first parsing the HTML from Greenstone and then a phase-specific template is used to generate an XML version of the HTML. The XML tags are based on two sources: the Dublin core meta-data[4], designed for use in digital library systems to capture important document data, and GML, Greenstone's own XML compliant markup language.

Translation to WML is also a two part process. First the data is extracted from the XML file and then, using a WML template, is converted to a WML file.

Architectural Benefits

Although having the interim XML phase added complexity to our translator, we identified a number of benefits which justify our decision:

- **Flexibility**: The system of templates and modularized components make the architecture very flexible and allows for alternate parsers and translators to be interchanged. For example, although WML forms the basis of current mobile solutions, the WML template can be replaced, allowing us to create output for future markup languages.
- **Robustness**: The five phase system can be applied in some way to even the most complicated digital libraries, thus allowing the architecture to be molded to fit different systems, by merely interchanging appropriate parsers and translators. The XML files provide a re-usable generic breakdown applicable to even the most complicated collection-orientated digital libraries.
- **Maintainability**: The aspects of flexibility and robustness ultimately lead to ease of system maintenance. The consistency and symmetry of the system modules make its components easy to identify, track and maintain. A procedure of system logging has been implemented to track parsing and translation progress through each stage allowing any other servlet interaction to be tracked. This creates the chance to track user requests and optimize their use of the system.

Architectural Problems

The system, the aim of which is ultimately to translate HTML to WML, has some problems due to the way in which programmers of mobile browsers implement the WAP and Internet protocols. Some WML browsers allow use of Java servlets while others do not; some allow the use of WML forms, while others do not; while some do not even allow the simplest of WML functionality. This makes it difficult to provide a solution for all browsers on different devices. For our purposes, we have limited our development to WML browsers (WapMAN, KWML, and CaphNet) on Palm OS – the most popular PDA platform.

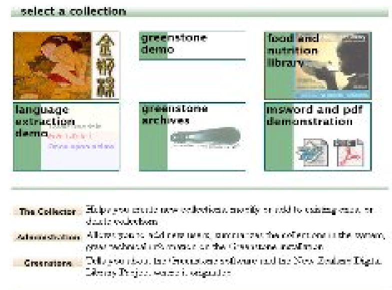
Design Constraints

The success of our solution lies, therefore, in being able to implement the five stages described in the previous section in a way which is effective on the small screen. We shall investigate each stage and the interface design decisions we have made in realizing them on the small screen.

Phase 1: Connection

The Connection page is laid out in a 3 x 2 spreadsheet format. Links to all of the available collections are represented as graphic buttons. Links to administrative functionality can be found at the bottom of the page.

HTML



WML

Given the limited graphic format available for WML (WBMP), all graphics were removed as they take a long time to load and add nothing to user interaction.

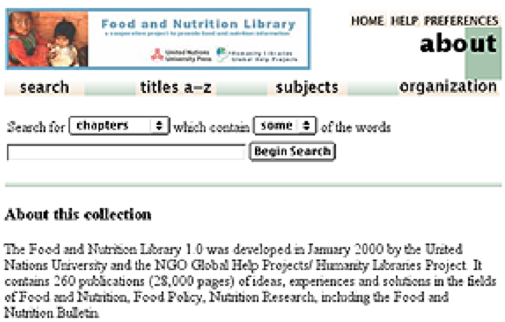
The link to each of the collections is represented in a list format. This was done to accommodate the limited screen width and thereby avoid horizontal scrolling, which, in our previous work, was shown to have a negative impact on text interpretation and the speed of site navigation.[8]

Although the representation of the collections in a list format increases the vertical length of the page (and thus the amount of vertical scrolling required), this is not a disadvantage: our studies have shown that vertical scrolling does not have a negative impact on either user interaction or site comprehension. Another motivation for using a list-like structure is that it provides somewhat of a 'site-outliner', which has been shown to improve small screen site navigation[9].

Phase 2: Collection Selection

The Collection Selection contains a navigation bar (hereafter referred to as the 'home' navigation bar) in the top right corner. The search bar (containing multiple search options such as title, organization etc.) can be found beneath the 'home' navigation bar. The user is then presented with the some text boxes and text fields in which directed search criteria can be entered. At the bottom of the page, information about the particular collection and the search types available for that collection can be found.

HTML



WML

Given the limited amount of screen space users' dislike of excessive scrolling, it was decided to remove the 'home' navigation bar from the main screen and create a button at the bottom of the page (Options) through which these features can be accessed. This has the twin benefits of freeing up screen space and placing these links beneath an always viewable/accessible link.

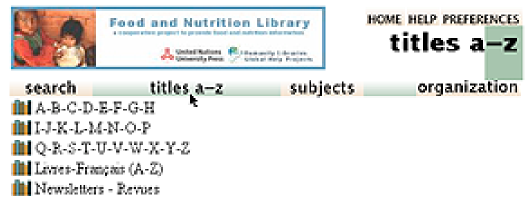
The search area is laid out in a list format, again to preserve space and prevent horizontal scrolling (for reasons already discussed above).

The information pertaining to a particular collection, as well as the information on search functions, has been left unchanged at the bottom of the page.

Phase 3: Browse Method Selection

The Browse Method Selection Page contains the 'home' navigation bar at the top of the page and presents the user with a list of browse options, depending on the search method chosen.

HTML



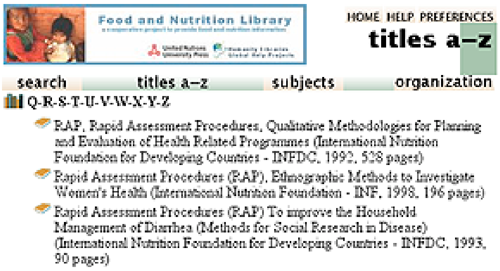
WML

The 'home' navigation bar has been moved to the 'Options' button, for reasons already stated. As the browse options are already represented in a list-like format the layout has not been changed.

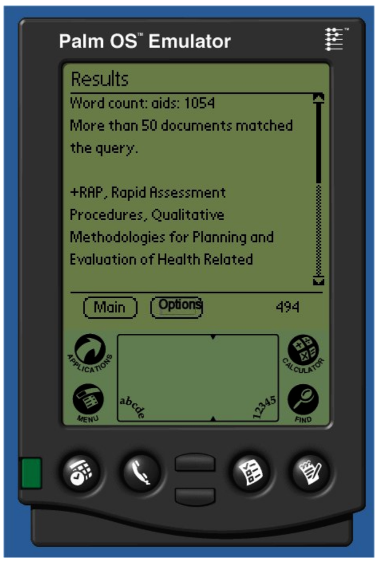
Phase 4: Browse

The Browse Page consists of the 'home' navigation bar at the top of the page, followed by the search bar and the results returned from the search. The results are displayed in a list format with a description of each result.

HTML



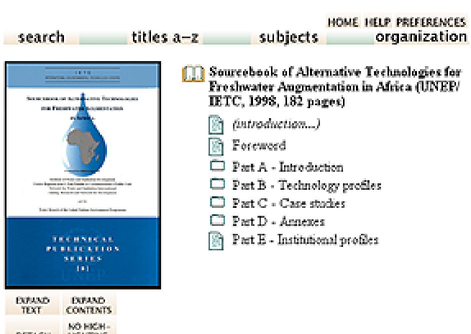
WML



The results returned are displayed in a list format. The description following the results has been condensed so as to avoid both horizontal and excessive vertical scrolling.

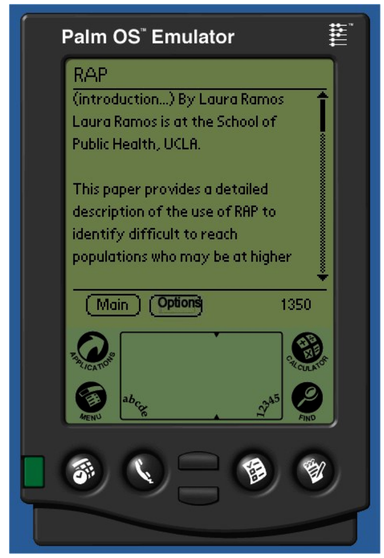
Phase 5: Article View

HTML



The Article View page contains both the 'home' and search navigation bars. The left hand side of the page is dominated by a graphic, while the right hand side contains links in a tree-like structure that allow the user to access the relevant sections of the chosen article. The chosen article section is displayed at the bottom of the page. The chosen article may or may not contain graphics in the form of pie charts, images and tables.

WML



Instead of displaying the tree-like structure, it was decided to load the entire article at once. This means that the user requires less clicks to access the article and less time will be spent loading the article; a decision supported by the work of Buyukkoten et al[2].

At the current stage, the ability of WML to support graphics is very limited. Even though the WBMP format is available, the limited screen size and resolution result in small, hard-to-interpret graphics. There are two solutions to this problem. One is to accept the low resolution and use an automatic GIF-to-WBMP translator (such as Wapaint[13]). The other is to store the image on the device to be downloaded to a desktop computer when one is available – this is not an acceptable solution for our aim of providing digital library access to those with no desktop computer. Although we could use automatic translation to WBMP, this was not seen as a priority for our system and has not, as yet, been implemented.

Besides the image issue, there is one remaining problem with translating Greenstone content to WML: that problem is tables. Although the WML specification supports tables, they are a subset of HTML tables – for instance, WML tables cannot be nested. At present, the best our system can do is extract the contents of an HTML table and lay it out as linear text.

FUTURE TECHNOLOGIES

At present, WAP is the standard protocol for mobile internet access in South Africa. As the network infrastructure advances to 2.5G networks and GPRS, we are likely to see an introduction of new protocols, which must be supported by our system. The two protocols most likely to be adopted are XHTML[15] and WAP 2.0[6]. Fortunately, both of these are XML compliant, which makes it easy for us to adapt our translators to support them. Furthermore, the more advanced formatting features of these protocols will allow us to overcome the table formatting problems we are currently encountering.

There is also much cause for hope in new handset technologies. One area in particular is the provision of better screens and better use of the screen (such as the Ericsson R380, which is sufficiently wide to significantly reduce the need for horizontal scrolling, which users find more troublesome than vertical scrolling[8]).

FUTURE RESEARCH

To date, our system has been designed and built taking into account the results from a wide range of user evaluations of small screen design. Although we have not yet conducted user evaluations of our system, we feel that it would be premature to do so until a better understanding is reached of how our target audience uses existing desktop based digital libraries and search engines. Without this knowledge, it would be hard to discern generic problems of literacy in using existing computer systems as opposed to those caused solely by the design of the mobile interaction system.

Consequently, we are working closely with the Center for Higher Education Development [3] at UCT and have undertaken studies into the problems encountered by non computer-literate users of on-line search tools[12]. Once these results have been fully interpreted, we will modify our system accordingly and conduct usability tests.

CONCLUSIONS

We have presented an argument that mobile internet technology and digital libraries have the potential to educate and empower a large section of South Africa's population that will never have access to the Internet through other means. In particular we identified the UNESCO collections of the Greenstone digital library project as being particularly relevant to the development of this country.

Our work, therefore, revolved around conducting an analysis of the interaction with Greenstone and constructing a generic model which would support interaction with Greenstone or any other similar digital library. This model was then implemented in a format which supports WML and future XML based technologies. In translating this interaction to the small screen, we have successfully applied research in small screen interaction to create an effective mobile interface to digital library collections.

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REFERENCES

1. ACM Digital Library. http://www.acm.org/dl/
2. Buyukkokten, O., Garci-Molina, H., Paepcke, A. & Winograd, T. Power Browser: Efficient Web Browsing for PDAs. *Proceedings CHI 2000*, pp. 430-437, 2000.
3. Center for Higher Education Development
   http://www.ched.uct.ac.za/
4. Dublin core meta-data http://dublincore.org/
5. Greenstone digital library http://nzdl.org/
6. GSM World http://www.gsmworld.org/
7. IBM Websphere Transcoding
   http://www.ibm.com/websphere
8. Jones, M., Marsden, G., Mohd-Nasir, N. & Boone, K. Improving web interaction in small screen displays. *Computer Networks* ,31, pp.1129-1137, 1999.
9. Jones M., Marsden, G., Mohd-Nasir, N. & Buchanan, G. A site based outliner for small screen Web access. *Poster presentation in 8th World Wide Web conference, Toronto*, 1999.
10. Marshall, C., Golovchinsky, G. & Price, M. Digital Libraries and Mobility. *Communications of the ACM*, 44:5 pp.55-56, 2001
11. May, P. Mobile Commerce. Cambridge, 2001.
12. Walton, M. & Marsden, G. Internationalization of Interfaces. *Proceedings CHI-SA*, 2001.
13. Wapaint WBMP translator http://www.wapaint.com/
14. Witten, I. Loots, M., Trujillo, M. & Bainbridge, D. The Promise of Digital Libraries in Developing Countries. *Communications of the ACM*, 44:5 pp.82-85, 2001.
15. World Wide Web consortium.
   http://www.w3c.org/MarkUp

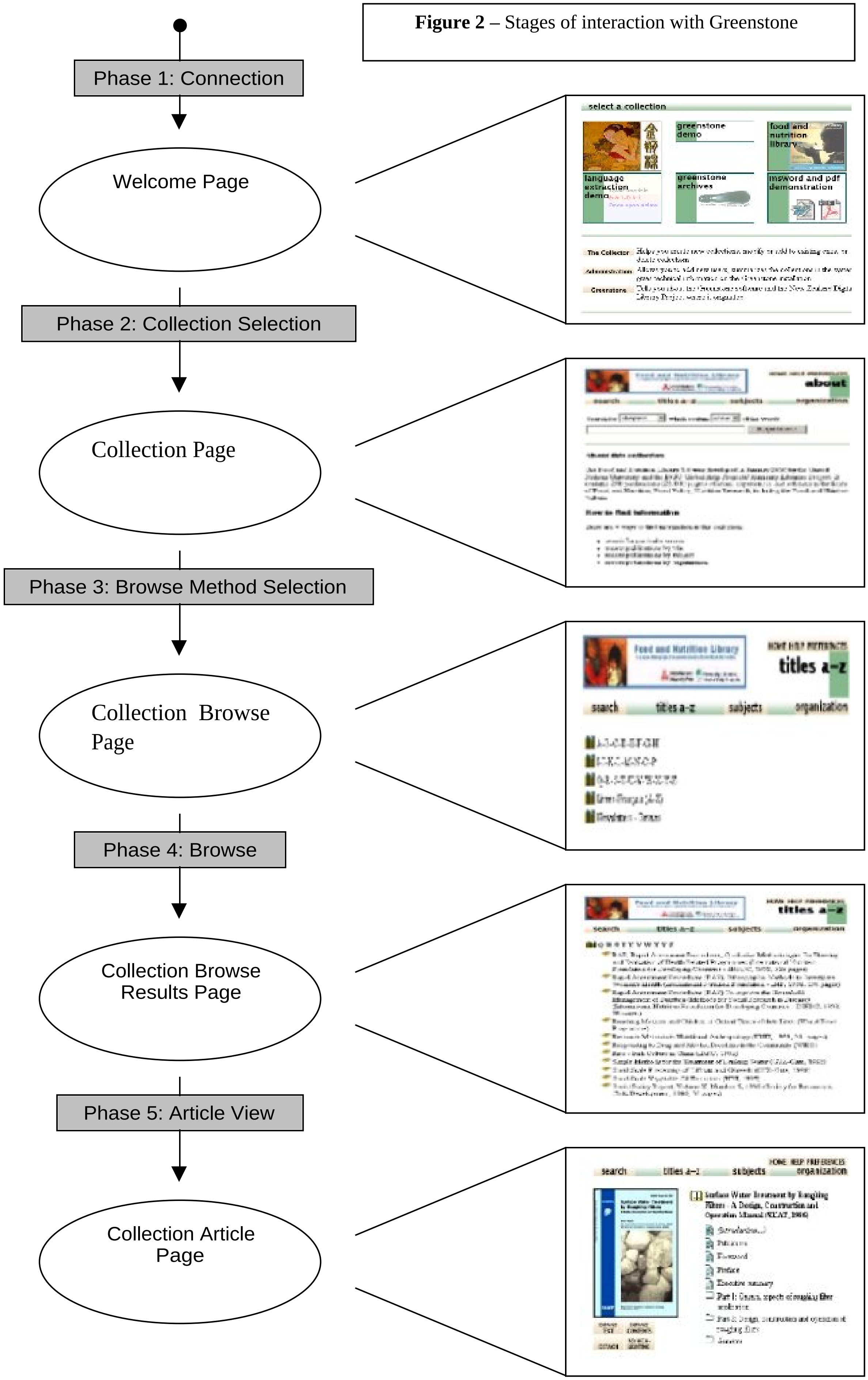

Figure 2 – Stages of interaction with Greenstone