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ABSTRACT

The need for information systems to support the dissemination and reuse of educational resources has sparked a number of large-scale digital library efforts. This article describes usability findings from one such project--the Digital Library for Earth System Education (DLESE)--focusing on its role in the process of educational resource reuse. Drawing upon a reuse model developed in the domain of software engineering, the reuse cycle is broken down into five stages: formulation of a reuse intention; location; comprehension; modification; and sharing. Using this model to analyze user studies in the DLESE project, several implications for library system design and library outreach activities are highlighted. One finding is that resource reuse occurs at different stages in the educational design process, and each stage imposes different and possibly conflicting requirements on digital library design. Another finding is that reuse is a distributed process across several artifacts, both within and outside of the library itself. In order for reuse to be successful, a usability line cannot be drawn at the library boundary, but instead must encompass both the library system and the educational resources themselves. (Contains 38 references.) (Author)

Looking at Digital Library Usability from a Reuse Perspective

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The need for information systems to support the dissemination and reuse of educational resources has sparked a number of large-scale digital library efforts. This article describes usability findings from one such project – the Digital Library for Earth System Education (DLESE) – focusing on its role in the process of educational resource reuse. Drawing upon a reuse model developed in the domain of software engineering, the reuse cycle is broken down into five stages: formulation of a reuse intention, location, comprehension, modification, and sharing. Using this model to analyze user studies in the DLESE project, several implications for library system design and library outreach activities are highlighted. One finding is that resource reuse occurs at different stages in the educational design process, and each stage imposes different and possibly conflicting requirements on digital library design. Another finding is that reuse is a distributed process across several artifacts, both within and outside of the library itself. In order for reuse to be successful, a usability line cannot be drawn at the library boundary, but instead must encompass both the library system and the educational resources themselves.

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1. INTRODUCTION
Science educators have repeatedly called for information systems that can effectively deliver quality educational materials in formats that are readily accessible, with a high degree of confidence that the materials will be useful, interesting, and effective [27]. This has largely been interpreted as a call for digital library systems or information systems with library-like services [16]. Towards this end, there are many digital library efforts underway aimed at improving the quality of undergraduate or K-12 science education [7, 23, 24]. Typically, these systems are similar to web portals, providing access to a managed collection of community-constructed educational resources with services for resource discovery, and possibly peer-review and resource creation as well. One prominent example of such a system is the NSDL (National Science, Mathematics, Engineering, and Technology Education Digital Library), a program initiated by the National Science Foundation to integrate multiple digital libraries in these areas and provide access to a broad variety of educational materials [36]. These efforts are based on the assumptions that providing digital libraries of educational resources can [21]:

- Improve the quality of education by promoting the reuse of educational resources that are proven to be effective;
- Improve the productivity of faculty through resource reuse and sharing;
- Help foster an active community of learning and innovation, where best practices and resources are developed and shared.

The underlying belief is that the *reuse* of existing resources or knowledge to create new educational resources will lead to improvements in both product (better educational resources) and process (teaching and learning). These assumptions and beliefs mirror similar goals for shared resource collections, henceforth referred to as 'repositories,' in both the business world and the software engineering community. In the business world, much recent activity has focused on using shared repositories to support 'knowledge management' and 'best practice' sharing to improve organizational efficiency and foster innovation [1, 17, 35]. The software engineering community has been vigorously promoting code sharing and software reuse for years since reuse is linked to measurable improvements in both programmer productivity and software quality [8, 10, 30, 31].

In the field of software engineering, reuse has been defined as the utilization of pre-existing components to ultimately create something new [10]. We feel that this is an appropriate definition for reuse of educational resources as well. For software developers, the product created might be an application; for educators it is a class or a curriculum. Although the products differ, we posit that the process of reuse in these two domains is essentially the same. Thus we feel that important lessons can be drawn from examining software engineering models of reuse: in particular, what promotes and what inhibits successful reuse.

Currently there is little research on the effects of reuse on learning. In literature from the library community [25], it has been observed that digital libraries can affect learning in different ways: through direct student interaction with the digital library system, and through the utilization of digital library resources by educators in their classroom. Studies show a positive correlation between learning and student interaction with a digital library [25]. Less is known about the relationship between educator reuse and learning. However, it is important to note that reuse is not an activity new to educators. On the contrary, the reuse process is deeply embedded in the way educators work today, as they locate, utilize and share physical as well as digital resources. In theory, digital libraries should support these current practices and extend them further, by making available a richer variety of educational resources, at all levels of granularity: ranging from single images, lesson plans and applets, to lab modules, to entire courses. Ideally, such facilities could enable educators to have more creativity and control of the materials they use in the classroom.

Past experiences in software engineering suggest that while a library is essential for supporting systematic reuse at the institutional level, simply providing a library of resources is insufficient to guarantee that effective reuse will occur at the individual level:

> *..., although the library metaphor has guided early work in classification, storage systems, and other areas of reuse technology, it does not provide the best focus for setting up and running a reuse program. [...], it has simply not yielded a major change in the way most people develop software.* Poulin, page 1, [30].

One survey on the state-of-the-practice in reuse found that (1) taking the library approach to software reuse and (2) the effectiveness or efficiency of the software library were two of the most significant *non*-predictors of reuse capability in an organization [31]. These results are quite disturbing given the current emphasis on 'digital libraries' as the primary means for facilitating the reuse of educational resources, and ultimately for changing the way that educators develop teaching resources.

In this article, we examine existing studies and theories on resource reuse from the software engineering literature. We believe that this prior research has much to offer digital library projects that are deeply concerned with fostering reuse within their communities of users. In particular, we develop and discuss a cognitive model of resource reuse derived from the software engineering literature – the location, comprehension, modification, and sharing cycle – and compare this model with existing digital library information lifecycle models. We focus mainly on comprehension and modification processes, as they are critical yet relatively understudied aspects of digital library use. We use this model to critically examine our own experiences with the Digital Library for Earth System Education (DLESE) project. This reformulation of the problem from 'providing a library' to 'supporting reuse' has significant implications for system design, community outreach and training, and future research directions, which we will discuss. We will first briefly present this model of reuse before proceeding to the analysis.

2. A MODEL OF REUSE

Reuse is cognitive activity that is embedded in an overall task-directed design process; as described above, the person's primary goal is to create something new. For instance, a faculty member may want to design a new lecture or even a new course, and may consider combining and reusing existing resources (e.g., lesson plans, exercises, maps, data sets) as part of this overall process. Reuse involves both composing new resources from existing resources and developing resources that can be reused in the future [9]. Previous studies of software programmers [8] suggest that when composing new resources from existing resources, reuse involves three closely intertwined cognitive activities: location, comprehension and modification (Figure 1).

As shown in Figure 1, the first step in the reuse process is forming a 'reuse intention'; i.e., deciding to use the resource repository in the first place. Ye et. al. outline numerous ways the reuse process can fail at this first step [38]. Software developers can be reluctant to disrupt their workflow and endure the cognitive effort it takes to switch back and forth between their development environment and the repository. Developers also chronically underestimate the amount of time it takes to develop from scratch, which leads to a cognitive bias against deciding to reuse in the first place. Ye argues that these behaviors stem from loss aversion tendencies in human decision-making processes; i.e., people are more sensitive to avoiding potential losses (like wasting time looking for resources that don't exist) than to realizing potential gains (finding a useful resource).

Location refers to the process of finding potentially useful resources in the resource repository. The user must be able to translate his or her reuse intentions (their situation model) into appropriate system queries (the system model) [12]. Numerous studies indicate the many people, not just software developers, have difficulties with this; Norman referred to this challenge as the gulf of execution and evaluation [26].

In reuse, location is tightly intertwined with comprehension. Comprehension involves not only making relevance judgments, but also understanding the function, structure, and context of use of the resource in order to decide if it needs modification and how to go about making the necessary modifications. Unsurprisingly, research has found that people are often unwilling to take the time to thoroughly comprehend a resource, and instead employ "comprehension avoidance" strategies [9]. For example, a developer might execute a piece of software to see what it does, rather than read all its documentation. Often times, developers just abandon the reuse process at this point.

Typically, resources cannot be used 'as is' but instead must be modified before they can be used. Modification can take many forms. Studies of the evolution of resources in software repositories show that software components evolve through four main processes: refinement, composition, abstraction, and factorization [9]. These processes will be defined and discussed in the following section. However, it is sufficient to note that many people drop out of the reuse cycle here because they are either unable to make the necessary changes (because they lack the technical skills or an adequate understanding of the resource), or are unable or unwilling to spend the necessary time.

In this context, 'sharing' refers to the resource producer making a conscious decision to make a new resource available to others to reuse and undergoing the work necessary to do so. Sharing resources is a crucial part of an effective and sustainable reuse cycle, but it is often viewed as being an extra step that is outside of the overall design process. Bannon and Bodker discuss the extra work it takes to place items into a shared resource repository [3]. They argue that both the resource producer and the resource

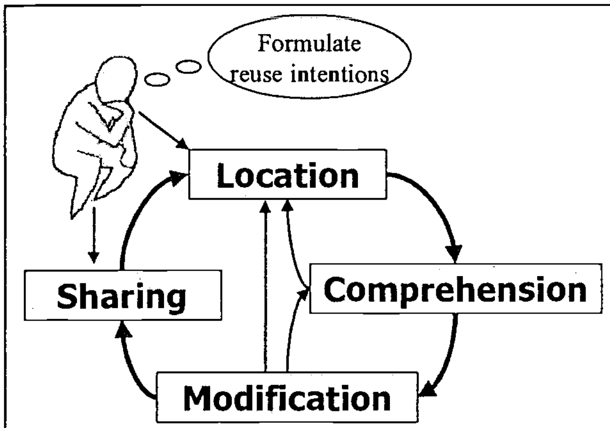

Figure 1: Location-Comprehension-Modification-Sharing Cycle (L-C-M-S)

consumer must make a conscious effort to understand each other's context of use and that reusability is enhanced when the producer can anticipate the consumer's context of use to some degree and makes the effort to 'package' aspects of this context with the resource. In software engineering, studies show that this packaging for reuse takes a significant effort and can double the production costs of more complex resources [10]. Many organizations have found it necessary to implement reward programs, often involving direct monetary compensation, to encourage developers to do the extra work required to submit resources to the repository [30].

In the following section, we will use this model to examine some of our experiences in the DLESE project, particularly noting the similarities and differences in the observed reuse behaviors of undergraduate teaching faculty and software developers.

3. CASE: DIGITAL LIBRARY FOR EARTH SYSTEM EDUCATION

DLESE is a grassroots, community-led project to provide searchable access to high-quality, online educational resources for K-12 and undergraduate earth system science education. These educational resources include objects such as maps, simulations, lesson plans, lab exercises, data sets, virtual field trips, etc. These resources are created by either individual faculty members or by institutions (e.g., NASA, USGS) and are held (stored) on their local servers. When resources are contributed to the library, either the resource creators or DLESE catalogers create metadata describing the resource to support resource discovery. The metadata scheme, based on the IMS LOM standard [14], is quite detailed and is fully described elsewhere [11]. This metadata is centrally stored and managed and is, in effect, the chief holding of the library.

As detailed in the DLESE Community Plan [19], the success of DLESE will ultimately be measured in two ways. Firstly, it will be measured by the library's impact on earth system science teaching and learning. Is student learning improved? Do faculty teach more effectively or efficiently? Both of these outcomes depend on faculty effectively reusing the resources available in DLESE in their own teaching. Secondly, success will be measured by the sustainability and viability of the community contribution process. Do faculty create reusable resources to share with others? Can they create the necessary metadata to help their colleagues discover and use their resources? Thus, success in DLESE heavily depends on faculty participating deeply in a culture of reuse in terms of both resource design and teaching practices.

For the past 18 months, the project has focused on building and evaluating a library prototype, designing a resource review process, and setting up the community governance structure [23]. Part of the current library interface is shown in Figure 2. Faculty can search by keyword and grade level to locate resources. The search results are presented as a list of information summarizing the potentially relevant resources such as resource title, brief description, grade level, etc. Clicking on either the resource title or URL will bring up the educational resource directly in a new browser window.

During this period, a number of formative studies were conducted to help us understand community needs and to evaluate the evolving library prototype. As part of the requirements analysis process, workplace interviews were conducted with seven earth science faculty and two students. Participants were selected that were already using digital resources in their teaching and learning. Each interview lasted between 60 to 90 minutes and was taped, transcribed, and analyzed. The focus of the interviews was to understand in detail how participants located and selected digital educational resources. We found that there is an important distinction in the way instructors prepare for a course, and for a class, which suggest that these two processes must be treated differently (Table1).

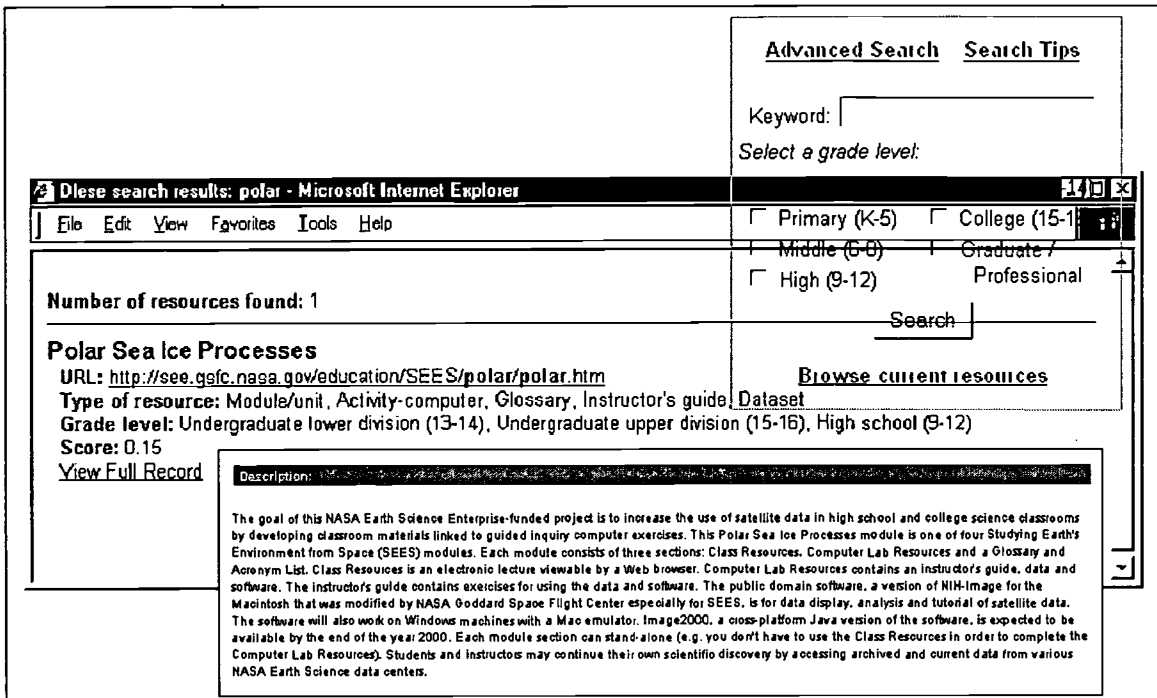

Figure 2. Discovery system interface in DLESE. The search interface is in the upper left corner. The search results page is shown in the middle. Clicking on 'View Full Record' brings up the full metadata record, which includes a short description of the resource.

When preparing for a class, educators are searching for items that will immediately plug in to the existing framework of their curriculum. In this task, reuse occurs *downstream* in the design process, where most of the overall design has been done, and so the search is highly targeted and specific according to the existing design. At this point educators are usually working under a severe time constraint, and don't have time to digest large amounts of information or adapt items for use. Thus they are looking for resources that are as *context independent* as possible, so that they require little adaptation effort. Such items include images, diagrams, vocabulary lists, and other resources that have minimal environmental or other dependencies.

Table 1. Two example DLESE tasks.

Prepare for a Class	Prepare for a Course
Jeff has an hour and a half before his class on environmental issues of greenhouse gases and ozone depletion. He wants to spice up his lecture. He browses online repositories he knows for pictures, charts, animations, or interactive tools to use during the class. He wants to conduct a pre-screening of sites for suitability and note the locations of these materials for his students, so they can study it further. The materials he uses must be from a source he trusts and be useable without a lot of alteration, since there is little time.	Kim is an introductory earth science teacher. She wants to teach her students about deep time, and how climate has varied over time in one location. She knows this is a difficult concept. She is looking for resources that can educate her in the area, as well as some pedagogical tools. In particular, she needs some help teaching students how to understand and get past their problems with "deep time." She would like to locate tutorials in this area, and experts in the field who she might be able to contact for teaching ideas.

This type of preparation is different from the work an educator goes through to prepare for a course. In this task, reuse plays a role *upstream* in the design process, in that much of the structure of the course itself is in a formative stage. Preparing for a course is generally on the time scale of weeks or months, rather than minutes or hours. In this process instructors appear to be more willing to explore new resources and test them for their classroom. They may have a vague idea of what they are looking for, and are interested in browsing collections to gain ideas. They can afford to take more time to synthesize larger resources and adapt them to their classroom, or design curriculum around them.

One of the challenges of designing a digital library is to support these two processes simultaneously, which can create tensions and conflicts in the system requirements. To analyze how well the evolving DLESE prototype supports these two key user tasks, we conducted two rounds of usability testing with earth science faculty (one with five participants and one with ten). Each participant was asked to think aloud as he or she performed a series of class and course preparation tasks using the current DLESE prototype. Detailed observational notes were independently taken by two observers and compared after each session. Additionally, we analyzed the structure and content of some of the resources with an eye towards developing heuristics for creating metadata that best facilitates location and resource comprehension. We now present the results of these studies and analysis in terms of the L-C-M-S reuse cycle. Table 2 summarizes the results for each of the two types of tasks.

3.1 Formulation of reuse intentions

Our research has shown that faculty formulate reuse intentions, as exemplified in the above reuse tasks taken directly from user interviews. We discovered that their primary source for identifying materials for reuse is through personal interaction of some kind: they ask colleagues for suggestions, they exchange ideas and resources at workshops and conferences, they even go to the library and ask the librarian for known sources. A crucial aspect of this process is the reliance on a trusted source for resource location and evaluation. Faculty appear to use the source (either the individual creator, or an institution) of the material as the primary way to determine its quality and effectiveness.

The Internet plays a role for many faculty in the reuse process, though this is highly dependent on the conditions of access and other environmental factors. However even in the best cases of Internet availability, we found that faculty do not commonly rely on search engines to locate resources, but rather go to sites that they already know and trust. Examples of trusted sites include colleague's personal home pages, or known organizations' websites, like NASA, USGS, or Discovery.com. In one case, a faculty member actually walked to the library and asked the librarian to search the web for a particular item, and then scribbled down the URL to later type in to his browser!

Faculty resist "cold" searching the web for a number of reasons: the thousands of hits returned by search engine queries and the time required to evaluate them; the frequently unrelated or low quality websites returned from a search query; and the many links that are broken or no longer point to relevant material. In short, web searching is perceived as inefficient and frustrating because of the enormous amount of information to sort through and high variability of quality of results.

The observation that instructors are only willing to visit and search trusted sites suggests that quality filtering for resources occurs mainly at the location stage, not at the comprehension stage as one might guess, in that faculty are resistant to even search sites with which they are not familiar. This finding echoes results from software engineering which found that while the perceived quality of the repository as a whole is an important factor, the certification of individual resources to some quality level appears to have no measurable impact on reuse [31].

Research has shown that an important factor in successful web searching is knowledge not only in the domain of the topic being searched, but also in techniques of web searching itself [13, 20]. In general, we observed that most faculty have a fairly low level of expertise in web searching, most likely due to lack of training. There is evidence that effective searching and evaluation are skills that need to be taught, regardless of the searcher's domain knowledge [15]. The most common search technique we observed for faculty was to type one or two keywords into a text box (although one faculty member claimed to always compose queries of one word or less). Many faculty did not recognize a difference between different search engines, and expressed frustration when different search engines returned divergent results to the same query. The frustration felt is equally due to the limitations and often minimal query support offered by current web search engines, which in many cases only provide a single search box with no instructions for query formulation.

When considering the World Wide Web as a repository, we have found that there is a gap between the formulation of reuse intentions, and the location of effective material. We have evidence from the interviews that faculty are forming reuse intentions, but these intentions are not being translated into an effective search strategy. The implication of this finding for the design of DLESE is two-fold: the system must provide better search capabilities than traditional search engines, and it must encourage and educate faculty to utilize this functionality. In other words, part of the role of DLESE is to help educators translate their intentions into an effective search query that will lead to the location of desired resources.

3.2 Location

The first step to successful location of resources through DLESE is to ensure that faculty know and accept DLESE as a trusted site. To make DLESE known in the community of earth science

Table 2. Examining two DLESE tasks from a reuse perspective.

	Forming reuse intentions	Location	Comprehension	Modification	Sharing
Preparing for a class	Downstream: Specific, well-defined	Highly targeted	Minimal time and effort available Comprehension avoidance	Little or none: Bookmark lists; Factorization of complex resources	Relatively easy
Preparing for a course	Upstream: Broad, loosely defined	May be explorative	More time and effort available Metadata records important Supplementary aids in resources (tables of contents, indexes, etc.) necessary	Modification likely: Composition of resources; Refinements	More effort required for 'packaging'

educators, the project has actively engaged the community in many aspects of DLESE development. It has also undergone extensive outreach efforts, which are described more fully in the DLESE Community Plan [19].

In order to best support our diverse audience, the DLESE resource discovery system has been designed to be both simple and powerful. One of the important advantages of DLESE over traditional search engines is that the resources are well described with a detailed metadata scheme, and therefore can be searched for in more powerful ways. The discovery system supports both searching and categorical browsing. These two search methods have been fully described and compared elsewhere [4, 37], and it has been shown that users often use a combination of both processes in the discovery process and it is important to support both. Browsing, in particular, supports search where the query is vague or explorative in nature, which may be the case in the task of preparing for a course.

In addition to entering keywords, the discovery system also allows the user to limit the search by specifying various search parameters (type of resource, grade level, computer requirements, etc.). In order to maintain a simple and easily usable discovery system, DLESE provides two different interfaces: a simple and advanced search. The simple search interface, shown in Figure 2, is similar to a common search engine and thus familiar to many users. It provides a text box for keywords and allows the user to specify the grade level of the resource. The advanced search interface supports other search parameters, such as educational resource type, and can be used by more advanced users.

After a search is executed, a results page is shown with a listing of the resources matching the search query. Along with the URL, some key information is shown for each resource: the title, brief description, grade level, and resource type. The quality and quantity of information presented at this stage is crucial both for resource location and comprehension, as described below. The user is also provided a link to the full metadata record for each resource. In preliminary studies, we have found that users frequently utilize the metadata record when evaluating the relevancy before visiting the resource itself, demonstrating that the two processes of location and comprehension are tightly intertwined.

3.3 Comprehension

As mentioned above, the comprehension of a resource begins with the search results page, so it is important that the results page provide the right type and right amount of information. In preliminary testing, we observed comprehension avoidance strategies at this stage, in the form of keyword scanning or skipping over text entirely, when the amount of information presented was considered too great. Interestingly, we found that there was not a graceful degradation of comprehension at this point, but rather complete failure because the text was ignored entirely if it was too long!

The design of the results page is one case where there exists a tension between supporting the two tasks described earlier: preparing for a course and preparing for a class. In the former, the instructor may want more detailed resource descriptions and secondary information, like suggested variations of use, related material, etc. In the latter case, where support for extremely rapid evaluation of a resource is essential, keywords and brief descriptions are ideal. These conflicting goals must be considered not only in the design of the search results page, but everywhere that comprehension takes place. This includes the presentation of the metadata record, and even the resource itself, as described below.

Possibly the most important finding is that comprehension is a distributed process across several artifacts, both within and outside of DLESE. Indeed, we observed instructors go back and forth between the search results page, the metadata description page for a particular resource, and the resource itself in the process of comprehension. This implies that in order to support reuse, all of these components must be considered.

A frequent and unexpected cause of failure at this stage was a granularity mismatch between what was promised by the metadata and what was actually displayed at the resource URL. For example, in one case an instructor restricted his search query to search only for lesson plans. The results page returned links to large educational sites that had numerous holdings, or entire courses that had lesson plans embedded in them. This was a frustrating and ultimately unsuccessful search experience for the instructor, as he expected to be taken to a lesson plan and instead was taken to a site where he had to search further. In many cases it was not at all obvious that the site was even relevant to the query the instructor had constructed.

An implication of the granularity mismatch problem is that the system needs to be designed to better support different levels of granularity of large websites. This problem manifests in both the comprehension and modification stages. The problem of defining what comprises an item vs. a collection in a digital library is an entire research topic on its own, but it is worth stating here that accurate correspondence between the metadata and the resource it points to is essential. To achieve this it may be necessary for DLESE to separately classify components of a resource, e.g. key images or lessons plans, with their own metadata and thus treat them as separate resources.

As mentioned above, we observed that failure in comprehension can occur at the resource itself, regardless of the level of detail or accuracy of the metadata. This implies that to be serious about reuse, we cannot draw a usability line at the library boundary. Usability of the resources held in the library is equally if not more important in the success of the reuse cycle as the rest of the library system. Thus, an essential function of the digital library is to encourage resource creators to create resources that are more usable. This can be viewed as a 'packaging' problem, which will be described in detail in the sharing section.

3.4 Modification

At first blush, modifying educational resources might appear to be outside of the purview of a digital library system like DLESE. Our studies, and experiences of other educational component libraries such as the Educational Object Economy project, suggest that many educational resources, even simple textual resources, need to be modified in some way before they can be used [34]. As mentioned earlier, studies of software repositories have observed resources to evolve through four main processes: composition, factorization, refinement, and abstraction. We have observed the first three processes in our studies, which we will discuss in turn.

Composition refers to creating a new resource by combining existing resources. We observed composition activities in both the preparing for a class and preparing for a course tasks. When preparing for a class, the instructor is typically looking for a resource with fairly specific requirements to plug into their existing lecture framework and is unwilling to spend much (if any) time in modification activities. However, instructors often also desire to create a compilation of pointers to interesting 'further reading' resources for the students to use after class. This type of bookmarking or list-creating activity is also observed in the planning stages when preparing for course. Interestingly, composition activities have received the most attention in the research community. There are many digital libraries, such as the ACM's, that provide simple bookmarking and bookmark sharing facilities. There are also more ambitious projects aimed at creating digital library tools and services to support more advanced forms of composition such as Walden Paths (a tool enabling teachers to construct linear paths through web resources) [33], Iscapes (a tool enabling faculty to create a collection of mixed media resources to share with their students) [28], and ESCOT (a set of tools and services which help faculty and software developers to combine interactive educational components without programming) [32].

Factorization refers to creating new resources by partitioning more complex resources into simpler parts that can be more easily shared. We observed the need for factoring in the granularity mismatches observed during 'preparing for a class' type tasks; i.e., the faculty member wants to find a lesson plan or a certain image but it is buried in a complex 'whole course' web site. There are several different approaches that could be taken to support factoring. One approach already mentioned would be to support it at cataloging time; i.e., create separate metadata records for each object in a complex resource. For example, a cataloger might break up a course by separately indexing particular units or even key images from the course. This is extremely effortful and time-intensive, and introduces the challenge of not returning many overlapping resources from the same complex object in response to a single query. Another approach would be to work with resource creators to encourage them to create these sorts of supplementary aids as part of the library's outreach activities. Alternatively, tools could be created that factor complex resources at comprehension time. For instance, when the user chooses to view an online course or other complex resource from the DLESE search results page, a computational tool could analyze the structure of the course to construct an active table of contents to all the main sections and major media elements. This could help both comprehension and modification processes by making the structure more readily apparent and by quickly identifying simpler parts that could be used separately. Our experiences suggest that support for factoring could be an important digital library service, but to the best of our knowledge there are no library projects currently looking at this area.

Refinement refers to creating a new resource by modifying or adding to an existing resource without significantly modifying its structure. For simple textual resources, refinements require a willingness and ability to engage in basic HTML authoring. For interactive resources such as simulations or visualizations, refinements could involve programming. Our resource analysis suggests that many resources, even simple textual ones, will require refinements before they can be used. As a mundane, yet pervasive example, we have observed that many educational resources cannot be reused 'as is' simply because they are overly specific; i.e., the contact details and classroom times and locations from the last time the resource producer taught are embedded directly in the resource. Research into end-user programming and authoring tools, such as that begin done in the ESCOT project, are looking at how to help faculty refine interactive resources [32]. Existing HTML authoring tools such as FrontPage™, Dreamweaver™, or even some word processors such as MS Word™, could be used to refine textual resources. However, many faculty may lack access to these tools, may not know how to use these tools, or may simply be unwilling to spend the time to switch to another application to make even simple changes. It would be fruitful to calculate more precisely the nature of many textual refinements; it may be the case that libraries such as DLESE could provide a tool with extremely simple editing functions that could deal with many of the necessary refinements.

Abstraction refers to identifying common features across several existing resources and creating a new resource that captures these commonalities. We did not observe abstraction processes in any of our studies or analyses. Our feeling is that abstraction processes may occur in more mature reuse communities, where there are multiple similar resources to generalize across and there are users willing and able to do this type of analysis.

3.5 Sharing

As discussed under comprehension and modification, many educational resources available on the web haven't been designed with reuse by other faculty in mind, and they are mainly focused on supporting students. Several educational publishers have also observed this, even for some commercial products:

> *"If the needs of the adopting instructor or the adopting community are considered along with the needs of the student, it will be much easier to transition the innovative work that is being done into the classroom at large."* [5]

Essentially, many faculty are placing resources on the web so that they can be used by students (notably theirs), but they are not taking the extra step to do the 'packaging'; i.e., to prepare the useful supplementary materials such as tables of contents, indexes, summaries, instructors guides, etc that make complex resources, such as courses, reusable by other faculty. Even for simpler resources like interactive applets, it is rare to find syllabi or lesson plans demonstrating how an applet might be used in a course [22]. Traditionally, these ancillary materials are developed and integrated into the resource as part of the publishing process [5, 22]. One challenge for educational libraries like DLESE will be to come up with alternative processes that encourage the development of such ancillaries.

At the moment, the metadata created by DLESE staff members for library resources is serving as the reuse 'packaging' to some degree. This metadata includes basic information on the content of the resource, technical requirements, and intended users. Thus, the reuse packing is in fact distributed across the library interface and the resource itself. In the usability testing, some participants were observed to make extensive use of the descriptive metadata records as comprehension aids, but then stumble when moving to the resource itself because the resource was not as clearly structured as the metadata. Other participants did not make use of the descriptive metadata, and some became frustrated trying to comprehend complex resources. One possible remedy would be for DLESE to provide services to resource creators to feed back some of the descriptive metadata into the resource itself. For instance, once the technical requirements are summarized for the metadata it would be fairly straightforward to embed this information in a summary section in the resource.

4. RELATED WORK

The L-C-M-S model shares some important similarities and differences to more general information lifecycle models proposed by others [6, 29]. Figure 3 shows the information lifecycle model developed by Borgman et. al [6]. One important difference between the models is that the Borgman model clumps location and comprehension into a single activity: searching. We believe that it is necessary to distinguish between these two steps, because it is important that both are supported. Being able to locate good material does not necessarily mean it will be comprehended, and the gap between these two stages is frequently where reuse fails. In effect, the L-C-M-S cycle is a much more specific model that depicts the specific demands of resource reuse from an individual's perspective, whereas the Borgman model depicts a general digital library process from the resource's perspective. Interestingly, Paepcke presents a rough model, based on the field studies of information needs in an engineering firm, consisting of five processes: discover, retrieve, interpret, manage, and share [29]. While this model highlights similar processes as being important, it does not develop the implications of these processes for digital library design and outreach, nor does it situate these processes into particular types of user tasks specifically, or a reuse process more generally.

As mentioned in the Introduction, in both software engineering and knowledge management, other approaches for supporting reuse have proven to be more effective than large, centrally managed libraries. Two promising alternatives are the product line approach [31] and the small, locally-managed library approach [2]. In the product line approach, the organization makes a concerted effort to analyze existing products and determine what underlying components are shared across products. 'Packaging' efforts are focused on making these identified components reusable, and subsequently, the product line is more easily maintained and expanded using these shared components. Perhaps an analogous approach could be applied to digital library outreach: facilitators could work with an educational program or department to identify shared components or opportunities for reuse across a suite of courses. In the small library approach, repositories are created with a narrow focus on either a specific domain (e.g., avionics software) or a suite of related tasks (e.g., financial analysis). Typically, these small libraries are locally run and managed, which often means that the resource producers and the resource consumers are part of the same workgroup. Reuse is easier in these cases because producers and consumers share a similar use context, which reduces the need for and reliance upon 'packaging'.

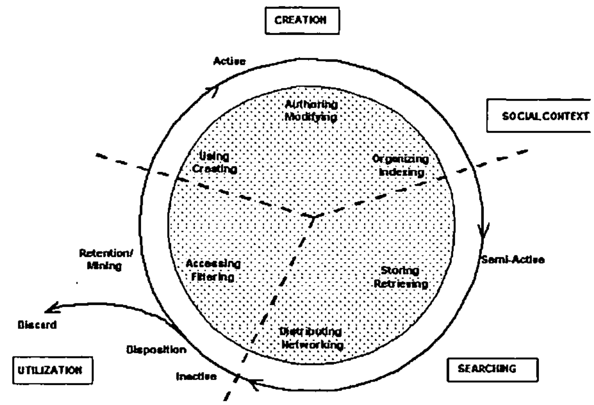

Figure 3. Information Life Cycle in Digital Libraries. Reprinted from Borgman, et.al. [6]

5. CONCLUSIONS

The preceding analysis falls into the broad category of task-centered design and analysis, which is a well-known approach to understanding software usability [18]. In our case, we examined two main tasks – preparing for a class and preparing for a course – from the perspective of a reuse model derived from the software engineering literature. We have tried to discuss how the experiences of faculty using a digital library in their teaching share some important similarities and differences to software engineers using a shared code repository. One of the key points highlighted by this analysis is that for these types of reuse tasks, we cannot draw a sharp boundary around the digital library system and only concern ourselves with the design and evaluation of the library itself. We must take into account the usability of the resources as well since the information necessary to complete the task, from the user's perspective, is distributed across the library and the resource. Analyzing our experiences from a reuse perspective highlighted several possible implications for library system design and library outreach activities.

In terms of system design, the design of the search results page is critical for supporting resource comprehension. There must be enough information to effectively summarize the resource, but not so much text that people skip reading it. Our evaluations show this to be a very fine line! Also, the library's metadata plays a central role in documenting the resource enough to support comprehension and modification processes. In effect, the descriptive metadata is 'filling in' for the lack of summarization and overview materials in the resources themselves. This observation has implications for the use of automatic cataloging tools or full-text retrieval methods. For these techniques to replace human catalogers creating metadata, they must be considered in terms of how well their output supports resource comprehension, in addition to supporting resource location.

The analysis of modification activities suggests that libraries could consider providing tools that support factorization and some simple refinement activities. While the DLESE community has always been interested in providing content creation tools as part of the library's services, modification tools have different needs in terms of functionality and in terms of when such a tool might be used. Our analysis suggests that these tools should be available in the context of the L-C-M-S cycle; thus they should be easily accessible from the search results page and designed to reduce context switching between the discovery system, the resource, and the tool itself.

In terms of library outreach, clearly one of the top priorities of the outreach effort should be helping potential library users associate resource reuse intentions with using DLESE. This is consistent with the focus of DLESE's current outreach activities. Perhaps more surprisingly is the strong need suggested by our analysis for outreach activities to work equally closely with resource creators. We must take steps to raise the level of the playing field overall in terms of designing and structuring educational resources for reuse by other faculty, not just students, and this may be part of the library's overall remit to 'manage' the collection. Currently, DLESE offers workshops on cataloging and metadata creation to interested resource creators. One possibility would be to extend these workshops to include a component on designing resources for effective reuse, which emphasizes the importance of clear labeling, summarizing, and indexing. Additionally, the 'product line' approach to promoting reuse suggests that outreach efforts might consider working with programs or departments, in addition to individual faculty members.

Finally, we tried to demonstrate that certain types of libraries, such as DLESE, serve as 'reuse repositories' and can benefit from prior reuse research in other disciplines. In the software engineering discipline, empirical studies have established that reuse improves software quality and programmer productivity [10]. This discipline has tried a number of approaches for fostering reuse in programming organizations, of which libraries are just one approach. To the best of our knowledge, no research has established the link between educational resource reuse and improved student learning or improved faculty productivity. Yet, this is the assumption underlying most educational digital library projects. Clearly research is needed that looks at whether resource reuse does improve teaching and learning, and under what conditions.

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7. REFERENCES

[1] Ackerman, M., Definitional and Contextual Issues in Organizational and Group Memories. in *Hawaiian International Conference on System Sciences (HICSS 27)*, (Hawaii (Jan), 1993), IEEE Computer Press.

[2] Ackerman, M. and Mandel, E. Memory in the Small: An Application to Provide Task-Based Organizational Memory for a Scientific Community, UC Irvine, 1997.

[3] Bannon, L. and Bødker, S. Constructing Common Information Spaces. in Hughes, J. ed. *Fifth European Conference on Computer Supported Cooperative Work, (Sep 7-11, Lancaster, UK)*, Kluwer Academic Publishers, The Netherlands, 1997, 81-96.

[4] Bilal, D. Children's Use of the Yahooligans! Web Search Engine: I. Cognitive, physical, and affective behaviors on fact-based search tasks. *Journal of the American Society for Information Science (JASIS)*, *51* (7). 646-665.

[5] Bondaryk, L. Publishing New Media in Higher Education: Overcoming the Adoption Hurdle. *Journal of Interactive Media in Education*, *98* (3). [www-jime.open.ac.uk/98/93].

[6] Borgman, C.L. Social Aspects of Digital Libraries, UCLA-NSF Social Aspects of Digital Libraries Workshop (February 15-17), 1996.

[7] Borgman, C.L., Gilliland-Swetland, A.J., Leazer, G.H., Mayer, R., Gwynn, D., Gazan, R. and Mautone, P. Evaluating Digital Libraries for Teaching and Learning in Undergraduate Education: A Case Study of the Alexandria Digital Earth Prototype (ADEPT). *Library Trends*, Fall 2000, Vol. 49, No. 2, 228 - 250.

[8] Fischer, G., Henninger, S.R. and Redmiles, D.F. Cognitive Tools for Locating and Comprehending Software Objects for Reuse *Thirteenth International Conference on Software Engineering (Austin, TX)*, IEEE Computer Society Press, Los Alamitos, CA, 1991, 318-328.

[9] Fischer, G., Redmiles, D., Williams, L., Puhr, G., Aoki, A. and Nakakoji, K. Beyond Object-Oriented Development: Where Current Object-Oriented Approaches Fall Short. *Human-Computer Interaction*, *10* (1). 79-119.

[10] Frakes, W. and Terry, C. Software Reuse: Metrics and Models. *ACM Computing Surveys*, *28* (2 (June)). 416-435.

[11] Ginger, K., Devaul, H., Kelly, K., Sumner, T.R. and Dawe, M. DLESE Metadata Working Group Homepage, Ginger, Katy, 2000.

[12] Henninger, S. An Evolutionary Approach to Constructing Effective Software Reuse Repositories. *ACM Transactions on Software Engineering and Methodology*, *6* (2). 111-140.

[13] Hoelscher, C. and Strube, G., Searching on the Web: Two Types of Expertise. in *22nd annual international ACM SIGIR conference on Research and development in information retrieval*, (Berkeley, CA, 1999).

[14] IMS. The Instructional Management System (IMS) Project, 1994.

[15] Jacobson, F.F. and Ignacio, E.N. Teaching Reflection: Information Seeking and Evaluation in a Digital Library Environment. *Library Trends*, *45* (4). 771-802.

[16] Khoo, M., Designing a Collection Review Policy: A Case Study. *Submitted to: Joint Conference on Digital Libraries*, (Roanoke, VA (June 24-28), 2001).

[17] Kuehn, O. and Abecker, A. Corporate Memories for Knowledge Management in Industrial Practice: Prospects and Challenges. *Journal of Universal Computer Science*, *3* (8 (Special Issue on Information Technology for Knowledge Management)). Springer Science Online.

[18] Lewis, C.H. and Rieman, J. *Task-centered User Interface Design: A Practical Guide*. http://home.att.net/~jrieman/jrtcdbk.html, 1993.

[19] Manduca, C. and Mogk, D. Digital Library for Earth System Education: A Community Plan, University of Oklahoma, 2000, 44, Aailable at: www.dlese.org.

[20] Marchionini, G. Information-Seeking Strategies of Novices Using a Full-Text Electronic Encyclopedia. *Journal of the American Society for Information Science (JASIS)*, *40* (1). 54-66.

[21] Marchionini, G. and Maurer, H. The Roles of Digital Libraries in Teaching and Learning. *Communications of the ACM*, *38* (4). 67-75.

[22] Marion, A. and Hacking, E. Educational Publishing and the World Wide Web. *Journal of Interactive Media in Education*, *98* (2). [www-jime.open.ac.uk/98/92].

[23] Marlino, M., Sumner, T.R., Fulker, D., Manduca, C. and Mogk, D. The Digital Library for Earth System Education: Building Community, Building the Library. *To appear in: Communications of the ACM, Special Issue on Digital Libraries (May)*.

[24] Muramatsu, B. and Agogino, A. NEEDS — The National Engineering Education Delivery System: A Digital Library for Engineering Education *D-Lib Magazine*, 1999, Available at:http://www.dlib.org/dlib/april99/muramatsu/04muramatsu.html.

[25] Neuman, D. Learning and the Digital Library. *Library Trends*, *45* (4). 687-707.

[26] Norman, D.A. *The Psychology of Everyday Things*. Basic Books, New York, 1988.

[27] NSF. Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology, National Science Foundation, Arlington, VA, 1996.

[28] Olsen, F. 'Iscapes' Combine Data Sets, Computer Models, and More to Solve Problems *The Chronicle of Higher Education*, 1999, http://chronicle.com/free/99/08/99082501t.htm.

[29] Paepcke, A. Digital Libraries: Searching Is Not Enough; What We Learned On-Site *D-Lib Magazine*, 1996, http://www.dlib.org/dlib/may96/stanford/05paepcke.html.

[30] Poulin, J.S., Balancing the need for large corporate and small domain-specific reuse libraries. in *ACM Symposium on Applied Computing*, (Phoenix, AZ (Mar 6-8), 1994), ACM Press, 88-93.

[31] Rine, D.C., Success factors for software reuse that are applicable across domains and businesse. in *ACM Symposium on Applied Computing*, (San Jose, CA (Feb 28 - Mar 1), 1997), 182-196.

[32] Roschelle, J., C. , DiGiano, C., Koutlis, M., Repenning, A., Phillips, J., Jackiw, N. and Suthers, D. Developing Educational Software Components. *IEEE Computer*, *32*. 50-58.

[33] Shipman, F., Furuta, R., Brenner, D., Chung, C. and H., H. Guided Paths through Web-Based Collections: Design, Experiences, and Adaptations. *Journal of the American Society for Information Science*, *5* (3). 260-272.

[34] Spohrer, J., Sumner, T.R. and Buckingham Shum, S. Educational Authoring Tools and the Educational Object Economy: Introduction to this Special Issue from the East/West Group. *Journal of Interactive Media in Education*, *98* (10). Available at: http://www-jime.open.ac.uk/98/10/.

[35] Sumner, T., Domingue, J., Zdrahal, Z., Hatala, M., Millican, A., Murray, J., Hinkelmann, K., Bernardi, A., Wess, S. and Traphöner, R., Enriching Representations of Work to Support Organisational Learning. in *1st Interdisciplinary Workshop on Building, Maintaining, and Using Organizational Memories (OM-98). In conjunction with the 13th biennial European Conference on Artificial Intelligence (ECAI -98)*, (Brighton, UK (August 23-24), 1998), 09-127.

[36] Wattenberg, F. A National Digital Library for Science,Mathematics, Engineering, and Technology Education *D-Lib Magazine*, Arlington, VA, 1998, Available at:http://www.dlib.org/dlib/october98/wattenberg/10wattenberg.html#contents.

[37] Xie, H.I. Shifts of Interactive Intentions and Information-Seeking Strategies in Interactive Information Retrieval. *Journal of the American Society for Information Science (JASIS)*, *51* (9). 841-857.

[38] Ye, Y., Fischer, G. and Reeves, B., Integrating active information delivery and reuse repository systems. in *Eighth international symposium on Foundations of software engineering for twenty-first century applications*, (San Diego, CA (Nov 6 - 10), 2000), ACM Press, 60-68.

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