Curriculum Development for Digital Libraries

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ABSTRACT

The Virginia Tech Department of Computer Science (VT CS) and the University of North Carolina at Chapel Hill School of Information and Library Science (UNC SILS) have launched a curriculum development project in the area of digital libraries. Educational resources will be developed based on the ACM/IEEE-CS Computing Curriculum 2001. Lesson plans and modules will be developed in a variety of areas (that cover the topics of papers and conference sessions in the field), evaluated by experts in those areas, and then pilot tested in CS and LIS courses. An analysis of papers on digital library-related topics from several corpora was performed, to identify the areas in which more and less work has already been performed on these topics; this analysis will guide the initial stages of this curriculum development.

Categories and Subject Descriptors

K.3.2 [Computers and Education]: Computer and Information Science Education – *computer science education, curriculum, information systems education.*

General Terms

Documentation, Design, Theory

Keywords

Digital libraries, Digital librarianship, Computer Science, Library and Information Science, Education, Curriculum development, 5S, CC2001

1. THE NEED FOR A DIGITAL LIBRARY CURRICULUM

There is an urgent need for curriculum development in the area of Digital Libraries (DLs). Hundreds of millions of dollars have been invested in DL research since the early 1990s, including research on how DLs can aid education, but there has been no parallel investment to support teaching and learning about DLs. Such research investment is of ongoing importance in the USA and elsewhere (e.g., in Australia, China, Europe, India, and Japan, where significant DL research is being conducted). It is, however, also important for moving to the next level of development: implementing DLs according to best practices. To be successful in this endeavor, more pilot studies and experimental systems (e.g., Google, which evolved from work at Stanford funded in 1994 by NSF's Digital Libraries Initiative [25]) should be implemented. Further, we must invest in the education of information professionals who fully understand the processes by which DLs are developed and their users are supported, as well as the potential of DLs for affording novel information services.

Without investment in education related to DLs, we face a future with many digital libraries, but few digital librarians to ensure their success. We run the risk of developers of DLs building software that is seriously flawed, as developers will not be aware of crucial requirements [7], efficient and effective techniques for implementation [20], or key ingredients of success [28]. End users already face a confusing situation where their ability to work with useful information is limited by failures of usability and inter-operability [24]. Sponsors of some early DLs now wonder about their sustainability [23], or are concerned about their long-term viability with regard to digital preservation [15]. Those involved in requirements analysis, design, development, management, and utilization of many types of related advanced information systems also face similar problems, which might be avoided with the help of those who have had formal training regarding DLs.

These issues are of primary concern in two related disciplines: Computer Science (CS) and Library and Information Science (LIS). For CS graduates, DLs represent an opportunity to further develop and apply new technologies, leading to integrated information systems that go beyond the currently popular divisions between portals, search engines, database systems, and multimedia/hypermedia (web) information systems. For LIS graduates, DLs represent an opportunity to apply these new technologies to providing library services to an increasingly diverse and distributed population of those needing access to digital information resources.

There is, however, currently only one formal degree program in digital librarianship in the USA: a pilot program at Indiana University and the University of Illinois at Urbana-Champaign, supported with funding from the Institute for Museum and Library Services. A handful of LIS programs worldwide have

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begun offering certificate programs in digital librarianship, and most of the LIS programs accredited by the American Library Association (www.ala.org/ala/accreditation/lisdirb/) offer courses and continuing education workshops on DLs or related topics, but there is little agreement as to the content and scope of these programs and courses, and little coordination between institutions, or between LIS and CS departments. While Computing Curriculum 2001 (CC2001, a joint effort of ACM and IEEE-CS published in late 2001, defining curricula for CS [4, 5] and related programs [18]) includes DLs as one of 14 knowledge modules in Information Management, no further work has been supported to develop a DL curriculum beyond the brief CC2001 description.

A further underlying problem is the lack of consensus on unifying formal theories and on an integrative and firm foundation for education related to DLs. This problem was highlighted by Licklider almost 40 years ago in his prescient book that anticipated the current interest in DLs [16]. The importance of work to develop a theory of DLs has been highlighted in an NSF-sponsored workshop to chart the future of the area [14].

2. THEORETICAL FOUNDATION: 5S

We believe that research and development in the DL area will flourish only if it has a firm theoretical foundation. Such a foundation would be particularly useful in guiding work on curricular and educational materials. Students then would be less burdened by the current confusion in terminology or by ad hoc organizations of topics, and should have an easier time organizing concepts in their own minds.

Towards that end, over the past six years, Fox and his students at Virginia Tech have been developing a formal model of DLs based on Streams, Structures, Spaces, Scenarios, and Societies, hereafter referred to as "5S" [8] (see Table 1). 5S captures the entities and media involved in DLs. "Streams" describe all types of content, as well as communications and flows over networks, or into sensors, or sense perceptions. "Structures" describe organizational schemes, including data structures, databases, and knowledge representations. "Spaces" cover 2D and 3D interfaces, GIS data, and representations of documents and queries. "Scenarios" are specified as system states and events, but also can represent situations of use by human users (or machine processes, yielding services or transformations of data). "Societies" describe both software "service managers" and generic "actors" who may be human users or machine processes, or collaborations of one or more of both.

5S uses fundamental mathematical and computer science formalisms, such as sets and graphs. These formalisms are expressive enough to capture the significant aspects of the social, philosophical, technological, and economic/ethical elements that relate to DLs. The most complete single description of this model currently available is contained in [8].

Several practical tools have been developed within the 5S framework: a language called 5SL [9] which can be used to develop formal specifications of a DL, a tool for visualizing DL models called 5SGraph [29] which can be used for visual semantic modeling of a DL, and a generator tool called 5SGen [12] which can be used for automatic generation of a componentized DL [27].

Table 1. The 5S framework

Ss	Examples	Formalization
Streams	Text, video, audio, image	Sequence (list)
Structures	Collection, catalog, hypertext, document, metadata, taxonomy	Graph, Function, Relation
Spaces	Used in indexing, browsing, and searching services – as well as interfaces	Set (vector, topological, measurable, measure, probability spaces)
Scenarios	Searching, browsing, recommending	States, events, sequences (lists)
Societies	Service managers (software), Actors (learners, teachers, etc.)	Tuple (relating events and actions)

From a pedagogical perspective, 5S makes things precise and provides perspective. The 5Ss are defined in terms of a small number of fundamental mathematical concepts. In turn, the 5Ss, individually or in combination, can be used to formally define each of the key objects that are needed to define a minimal DL [10]. Building on this foundation, subsequent work has shown how to formalize a DL ontology, and to specify all of the services found in a typical DL [8].

Further development of the 5S model/theory will allow us to define critical dimensions and measures of DL quality. The formal and digital nature of DLs allows both precise definition of quality metrics and automatic assessment and enforcing of those quality properties [8]. If students studying DLs can learn to think clearly about key DL concepts, and can develop high-quality systems and services, there will be a strong positive impact on DL education, development, and practice.

3. APPROACH TO CURRICULUM DEVELOPMENT

The authors have recently launched a curriculum development project in the area of DLs, funded by the U.S. National Science Foundation.[1] This curriculum development will adhere to the preliminary framework illustrated in Figure 1. For programs emphasizing digital libraries, a two-semester sequence might be appropriate. For more general Computer Science (CS) or Library and Information Science (LIS) programs, a one-semester course may be most popular. As an alternative or in addition to a single course, modules on one or more of the core and/or related DL topics might be implemented within courses: e.g., on databases, HCI, information retrieval, multimedia, or the Web. The mission of a particular school will affect the emphasis placed on DLs within its curriculum. We therefore are developing educational materials at three levels of granularity: 1) lesson plans on specific topics (both core and related topics, as shown in Figure 1) that can be implemented as a segment of a single class section or as an

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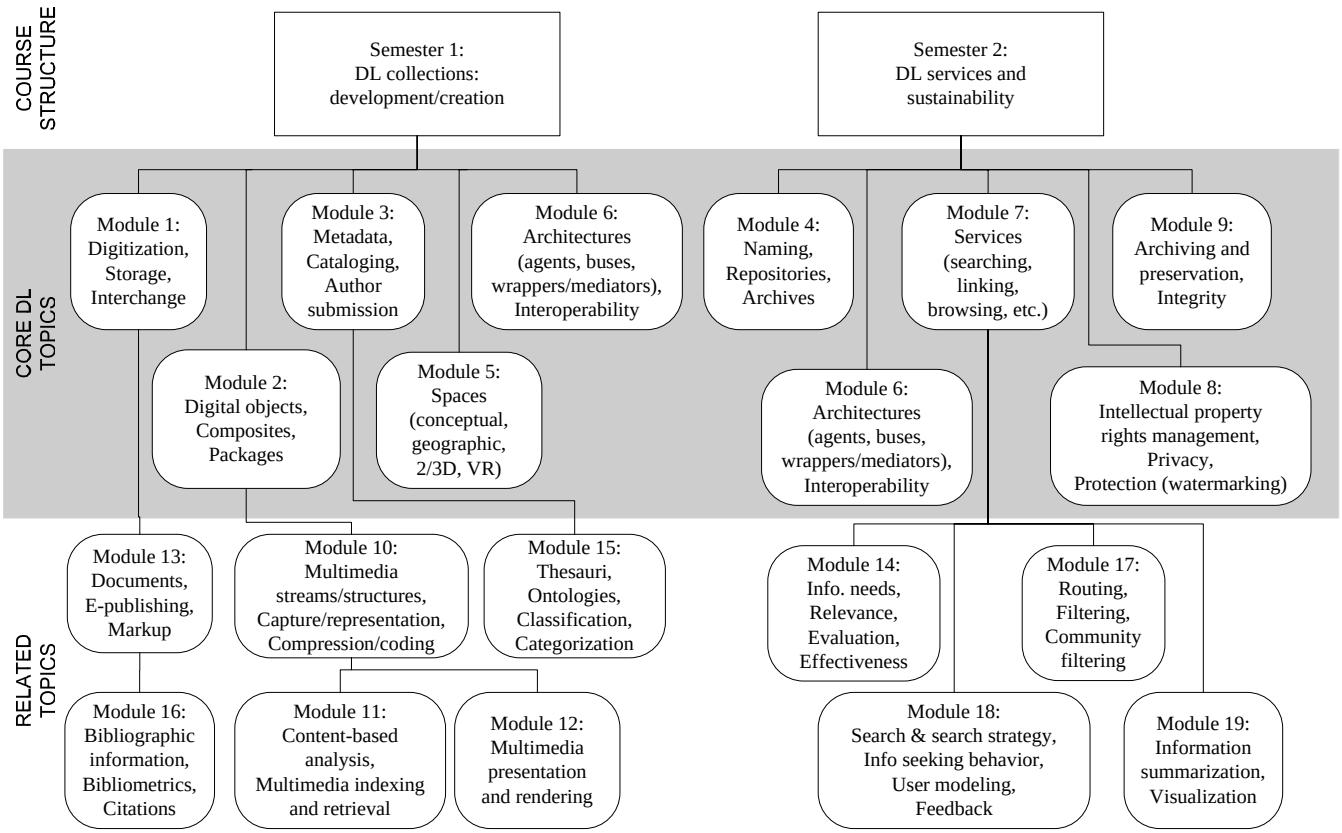

Figure 1. Curriculum framework

exercise within a class session, within the context of a DL or related course; 2) educational modules on specific topics that can span one or several class sessions; and 3) course syllabi and a textbook appropriate for one or two semester-long courses.

The topics listed in Figure 1 are based on a careful analysis of the CC2001 discussion regarding the field of Information Management (see www.sigcse.org/cc2001/IM.html). We focus on the three core areas (Information models and systems, Database systems, and Data modeling), as well as the four elective areas most related to Library and Information Science (Information storage and retrieval, Hypertext and hypermedia, Multimedia information and systems, and Digital libraries). CC2001 lists a set of topics under each of these areas; those topics that address or are most related to core aspects of DLs are shown in the middle and bottom portions of Figure 1, respectively. A preliminary analysis of the published literature on DLs indicates that a great many papers have been published on Services for DLs, followed by Architecture, Content-based information retrieval, and Searching and user information seeking behavior.

The authors' work on DL curriculum development will build upon the prior work of CC2001 and related curriculum development efforts [1, 6], and our experiences at VT and UNC-CH. It is, however, also important to involve the DL community more broadly so as to ensure the intellectual merit and broad impact of our project. Accordingly we have asked key individuals (leading researchers, educators, and practitioners) in the DL area to serve on an Advisory Board. These experts will assist with the identification of topics on which modules will be created, and will advise on the development of these modules. In particular, they will help us to define the scope of each topic and module and to determine which aspects of each topic are most relevant to particular curricular goals.

Educational modules will be developed (or adapted from those pre-existing) in accordance with CC2001 guidelines. There is no similar curriculum document to CC2001 in the LIS field, but many LIS schools currently offer courses on DLs and related topics, and work is currently underway in several LIS schools to develop internships, certificate programs, continuing education workshops, and post-Masters degree programs on digital librarianship. This project will build on these existing efforts by identifying best practices from these courses and programs, and integrating these practices into the developing educational modules. These educational modules will then be provided to institutions working with CC2001 and to interested LIS schools, to implement in their courses. Feedback will allow iterative refinement of the courseware being prepared.

The module on Services, for example, will include coverage of both automated and human-intermediated services. Automated services include searching, linking, browsing, and other methods that can be instantiated in software, by which a user can interact with or manipulate data. Human-intermediated services include digital reference, question answering, and other methods by which an intermediary can provide assistance to a user who interacts with data. This module will include topics such as

policies and procedures for integrating human intermediation into DL collections, and for integration of automation into traditionally human-intermediated services. This module will address both 1) the creation of "special collections" within a DL by creating sets of related links, and 2) issues involved in collecting and "de-identifying" [21] answered questions.

Each module will be made up of a variety of materials. These will include lecture outlines, suggested readings for the students, and supplementary readings for faculty members adopting the modules. They also might include in-class or online exercises, case studies for stimulating class discussion or to be used as the basis for an assignment, and/or interactive software demonstrating key concepts. The modules will package all these components to provide rich and coherent coverage of a particular topic.

The educational modules will themselves be decomposable, so that they can be implemented at various depths of coverage. The modules will be developed such that they can be implemented in their fullest form in some courses, and in scaled-down versions (i.e., as individual lessons) in other courses. The module on Information Visualization, for example, will include material on 3D representations, which will be important to address in full in CS courses, but which may be addressed more briefly in LIS courses. The module on Thesauri, for example, will include material on theories and approaches to classification, which will be important to address in full in LIS courses, but which may be addressed more briefly in CS courses. By designing these modules to be scalable, they will be accessible to a greater range of audiences in CS, LIS, and other programs.

In addition, this effort will build upon educational research undertaken by many others. For example, plans for developing learning modules will build upon the original work by Keller on the Personalized System of Instruction [13]. Some materials will be developed through a constructivist approach [2], and some will support laboratory-based approaches [11]. Concept maps representing both individual modules and the relationships among modules will be developed, building upon work by Novak and others [22], and benefiting from results of the NSF-funded GetSmart project [17].

4. MODULE TOPICS

The modules shown in Figure 1 are based on an analysis of the CC2001 recommendations. Since the choice of a set of modules has far reaching implications for the duration of our project, we sought a quantitative approach to validate the selection, or to refine it as appropriate. We selected two corpora to work from. Our first corpus contained the complete runs of the ACM International Conference on Digital Libraries and the JCDL conference, and the complete run of *D-Lib Magazine* (see Table 2). We decided to undertake a manual classification of the papers in these corpora, with the intention that the processes developed during the course of this classification task could later be used to develop supervised machine learning methods for conducting future classification tasks. For this manual classification task, a simplified set of modules was developed by categorizing the topics shown in Figure 1 according to the 5S model. This simplified set of modules is shown in Table 3. Every paper in the corpus was assigned to a single module most closely related to the paper's content focus. This assignment was performed using methods employed by librarians assigning subject headings:

Table 2. Corpus 1: Papers studied, by source

Source	Year & Coverage	Number of papers
JCDL 05	2005	59
JCDL 04	2004	63
JCDL 03	2003	54
JCDL 02	2002	68
JCDL 01	2001	110
ACM DL 00	2000	44
ACM DL 99	1999	50
ACM DL 98	1998	49
ACM DL 97	1997	28
ACM DL 96	1996	18
D-Lib 06	Jan-Feb 2006	9
D-Lib 05	2005	53
D-Lib 04	2004	40
D-Lib 03	2003	52
D-Lib 02	2002	47
D-Lib 01	2001	45
D-Lib 00	2000	48
D-Lib 99	1999	50
D-Lib 98	1998	51
D-Lib 97	1997	58
D-Lib 96	1996	49
D-Lib 95	Jul-Dec 1995	19

Table 3. Modules according to the 5S model

Streams	1. Collection Development
	2. Digital objects/ Composites/Packages
Structures	3. Metadata, Cataloging, Author submission
	4. Architecture, Interoperability
Spaces	5. Data visualization
Scenarios	6. Services
Societies	7. Intellectual property rights management, Privacy, Protection
	8. Social issues / Future of DLs
	9. Archiving and Preservation

reading the title and abstract, and skimming the actual paper to achieve an understanding of the paper's content.

The distribution of conference papers is illustrated in Figure 2, and the distribution of *D-Lib Magazine* articles is illustrated in Figure 3. Summing across all years, the greatest number of papers have been published in module 6 (Services) and module 4 (Architecture), both in the conferences and in D-Lib. These results demonstrate that there are significant similarities within the literature on digital library across different venues. There are, however, shifts in topical coverage over the years.

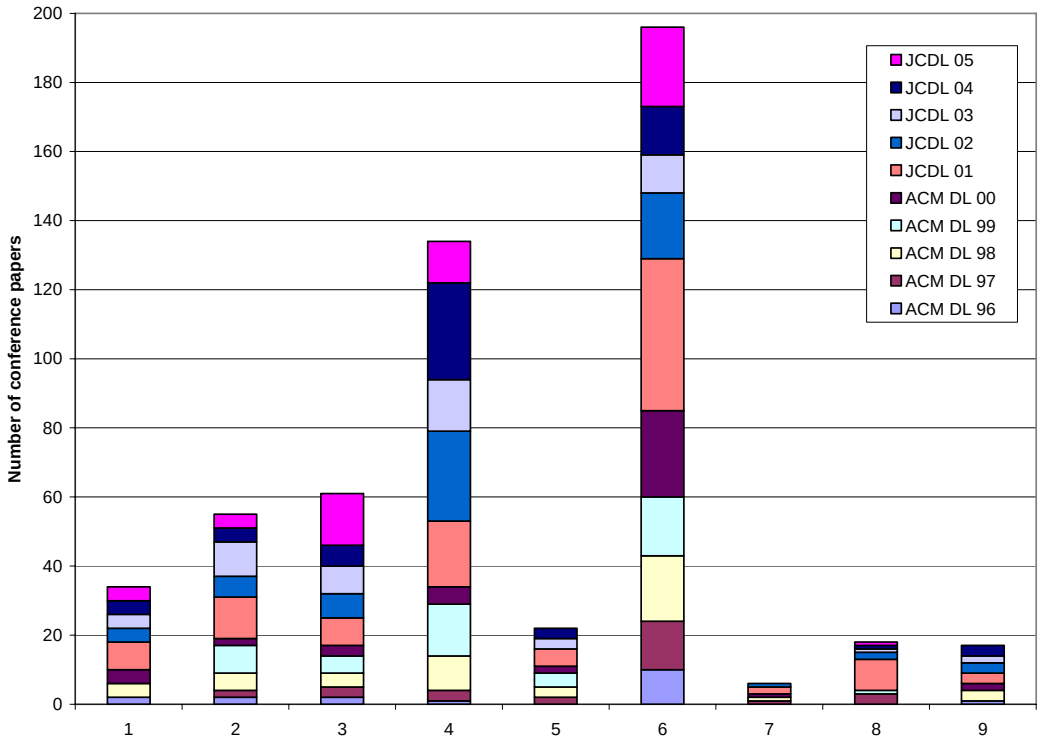

Figure 2. Distribution of conference papers across module topics

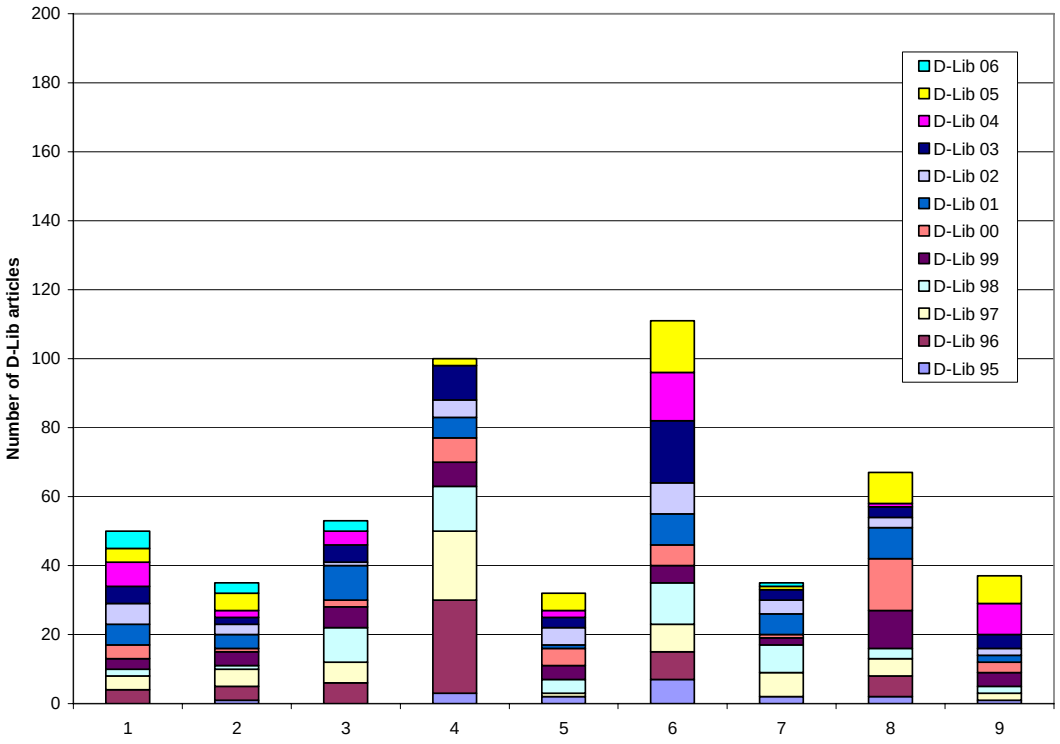

Figure 3. Distribution of D-Lib Magazine papers across module topics

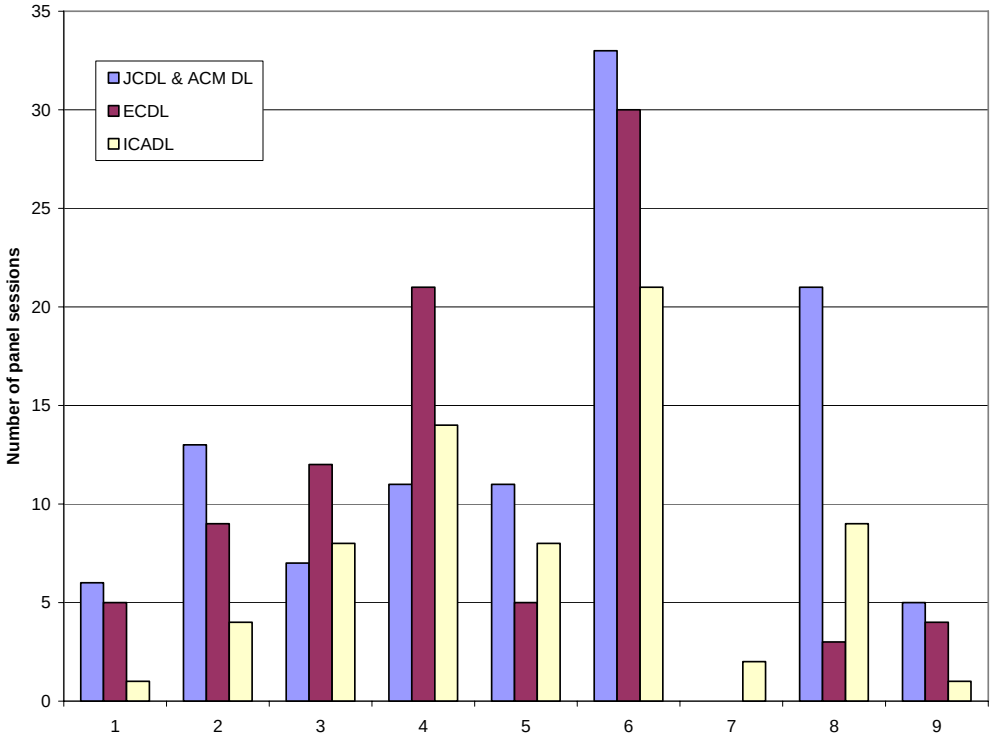

Figure 4. Distribution of session titles across module topics

Our second corpus was of panel sessions at conferences (see Table 4). We analyzed conference panels because they abstract the topics of multiple papers, and tend to reflect "hot topics": subjects that are of interest to conference attendees and organizers in any given year. To get more of an international flavor, we selected the leading DL conferences in the Americas, Europe, and Asia. The distribution of conference sessions is illustrated in Figure 4. The module topics on which the greatest number of sessions have been conducted are again modules 6 and 4, though module 8 (Social issues) also makes a strong showing. In general, the topics covered at these conferences mirror each other quite closely, indicating that interests are shared globally.

Those responsible for conference planning and publications related to digital libraries may wish to reflect upon this analysis. We will seek comments at the JCDL conference and after, from experts regarding the selection of modules, and their relative importance, in the light of this data.

One further type of analysis was conducted, making use of the data collected. Since words and phrases are often used in categorization systems, we identified the most popular ones, based upon the appearance of these words and phrases in the titles of papers and sessions (taken from the sources described in Tables 2 and 4).

Table 5 gives a partial list of the most frequent words in the titles of DL papers and sessions. In many cases it is possible to map these words to module topics (e.g., metadata, preservation). However, in other cases (e.g., open, report, technology), the words are ambiguous and do not fall neatly into specific module topics.

Table 4. Corpus 2: Session titles studied, by source

Source	Year	Count
JCDL	2005	18
JCDL	2004	18
JCDL	2003	13
JCDL	2002	18
JCDL	2001	18
ACM DL	1997	10
ACM DL	1996	12
ECDL	2005	11
ECDL	2004	14
ECDL	2003	13
ECDL	2002	13
ECDL	2001	8

Source	Year	Count
ECDL	2000	8
ECDL	1999	7
ECDL	1998	9
ECDL	1997	6
ICADL	2005	13
ICADL	2004	7
ICADL	2003	17
ICADL	2002	12
ICADL	2000	7
ICADL	1999	6
ICADL	1998	6
Total		264

5. DEVELOPMENT AND EVALUATION

Figure 5 summarizes the development and evaluation process for the project. The process will begin with the development and refinement of the overall vision/plan for the project, with input from the Advisory Board and other experts (e.g., those attending the Joint Conference on Digital Libraries). These inputs will be analyzed in terms of curricular needs, as well as the background of the students who might be interested in focusing on digital

libraries in their studies. This analysis will occur within the context of the curricular specifications in CC2001.

Based on this analysis, modules supporting whole topics will be designed, as well as individual lessons supporting particular aspects of those topics. Several modules, including separate lessons within those modules, will be designed during each year of this 3-year project.

As the design of a module/lesson is completed, a formative evaluation of it will be conducted. The primary criterion for evaluating the design of the modules is the learning of the students in the courses in which they are incorporated: Did the students gain the specified knowledge?

Considering the theoretical context of Bloom's taxonomy [3], we would expect that students learning about digital libraries from these modules would be able to: retain knowledge of key terminology and facts, comprehend the meaning of important concepts presented, apply their knowledge to realistic problems, analyze the structure/relationships among the concepts presented, synthesize and apply their new knowledge to novel problems in digital libraries, and evaluate alternative approaches to particular aspects of digital libraries.

This framework will be applied to the modules/lessons. Each such unit will be inspected and evaluated by at least five experts, who together will represent both CS and LIS perspectives on the module or lesson. We will identify evaluators from within the DL research and teaching community who have particular expertise in the topics covered by the modules. Each expert will be asked to inspect the module/lesson carefully, in relation to the level of Bloom's taxonomy expected to be attained by the students, in terms of: 1) its coverage of the topic, 2) the currency and appropriateness of the readings undergirding the unit, and 3) any assignments or exercises associated with the unit. In addition to evaluating the unit, each expert will be asked for suggestions for improving the unit with regard to use in CS and LIS courses.

This formative evaluation will occur early in the semester prior to implementation. Based on this evaluation, the suggested revisions will be made to each module's design.

During the following semester, one or more instructors will be asked to implement the module within the context of a course related to DLs. Much of this field testing will be carried out at Virginia Tech and UNC-CH; however, other institutions also are being sought to participate in field testing of the modules. The participating instructors will be asked to implement the modules as they are specified, with no undocumented additional customization, in order to gather evaluations of the units as specified by the research team.

We will gather data from two sources during this second, summative evaluation phase. The first source will be the instructors implementing modules in their courses. Based on their experiences, these instructors will be asked questions similar to those posed to the experts in the formative evaluation: 1) whether the unit adequately covered the topic, 2) whether the assigned/suggested readings were current and appropriate, and 3) which levels of Bloom's taxonomy were addressed by the assignments and exercises associated with the unit.

Table 5. Most frequently-used words and phrases in DL paper and session titles

Word	Papers	Sessions
digital librar(y/ies)	328	97
information	97	33
user(s)	40	28
metadata	55	13
web	62	5
retrieval	41	23
archive(s/ing/al)	59	3
search(ing)	51	10
service(s)	54	6
data	47	7
collection(s)	42	11
access	51	2
project(s)	53	
education(al)	41	7
resource(s)	46	2
content(-based)	44	3
building	35	9
technolog(y/ies)	30	13
document(s)	37	4
approach(es)	35	3
management	31	7
model(s/ing)	29	7
research	35	
preserv(e/ed/ation)	29	6
open	34	1
architecture(s)	24	10
evaluation(s)	24	6
use(s)	24	5
multimedia	14	12
report(s)	24	
tool(s)	11	12
issues	17	6
technique(s)	6	14
track(s)		18
knowledge	8	9
interaction(s)	2	11

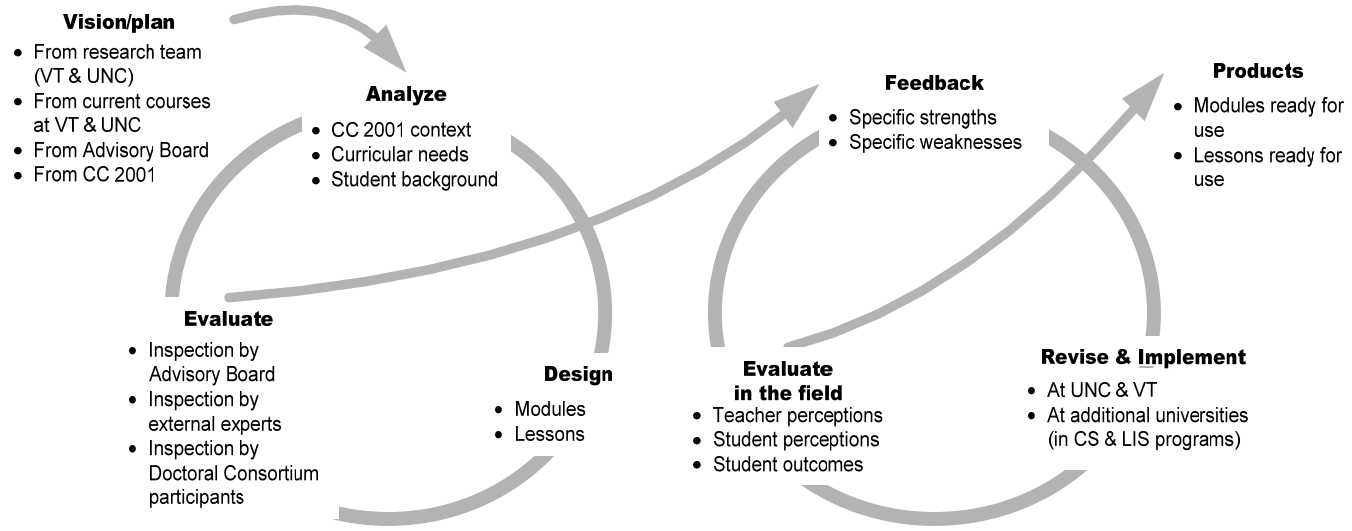

Figure 5. The development and evaluation process

While the substance of this evaluation is parallel to that of the earlier evaluation, it will be based on the instructor's direct experience with implementation of the module/lesson, rather than on the expert's view unaided by direct experience.

The second source of data for this summative evaluation is the students who are learning from the modules and/or lessons. As data on student perceptions of the modules is gathered, the primary challenge is to disambiguate their perceptions of the modules from their perceptions of the instructor and student-teacher interactions. Therefore, the standard end-of-course questionnaires typically used to evaluate instructor performance will not be used; instead, alternative methods will be used, focusing on students' evaluations of the course content and their effort and learning in the course. While a final selection of instrument has not been made, we expect to adopt a questionnaire similar to that proposed by Snare [26] or the student learning and student satisfaction scales suggested by McGorry [19]. Each student in the courses implementing the modules will be asked to fill out a questionnaire evaluating the unit immediately after its completion (when the student's memory of that specific unit within the course is clearest).

The data on teachers' and students' perceptions will be augmented by an examination of the students' performance related to the modules implemented. Teachers will not be asked to use any evaluation methods that they would not normally use, but they will be asked to share with us any assignments or tests completed in relation to the module(s) implemented. These performance results will be triangulated with the perceptual data in order to understand the learning outcomes resulting from the implementation of the modules.

Using these methods, several modules and their associated lessons will be evaluated in the field during 2007, and more will be evaluated in the field during 2008. This evaluation process may be repeated each time a module is implemented in the classroom.

In summary, both formative and summative evaluations of the modules developed as part of this project will be undertaken in a way that is consistent with CC2001's recommendations. CC2001 specifies that some of the questions that should be asked during course assessment include the following [4, section 12.2.4]:

- "Has any important topic been omitted? Is anything unnecessarily included?"
- "Based on examination results and course evaluations, do students completing the course possess the desired skills, knowledge, and capabilities?"
- "Is the client… satisfied with our course offering? If not, what can we do to improve their satisfaction?"

6. CONCLUSION

It is expected that the courses, modules, and lessons developed by this project will have a strong positive impact on the education of the next generation of digital librarians and DL developers, and will provide a firm foundation for digital library education in both CS and LIS programs. Eighteen or more modules, each made up of several separable lessons, and structured in such a way that they can be formed into coherent courses, will provide educators with a strong basis for locally-customized curricula in digital libraries. These modules may be freely disseminated and implemented by instructors in CS and LIS programs. The participation of a large number of experts in the development and evaluation of these materials will help to speed further their dissemination into the leading schools in the USA and abroad. The work of graduates of those schools, as well as those connected with the annual JCDL-connected Doctoral Seminar, will yield benefits very quickly in the development and management of DLs and the provision of DL services. More broadly, this effort should help advance the DL area by ensuring a firm foundation and basis of understanding for all involved in learning, teaching, and R&D.

The one piece of this project that is currently missing is a large number of individuals willing to participate. The authors are seeking individual instructors interested in developing courses, modules, and lessons, as well as instructors, schools, and departments interested in implementing and evaluating these courses, modules, and lessons. This project will be most successful with maximum participation from both the CS and LIS education communities. In turn, this project has the potential to contribute materials to CS and LIS programs that will assist instructors in their teaching, and enrich students' experiences. Anyone interested in participating in this project should contact any of the authors.

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