Framework and Strategies for Integrating Metadata Concepts with Geographic Information Science Curricula

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Abstract: *Metadata is emerging as an increasingly important component of geographic information science research and education. Metadata should not be viewed merely as a content standard or software application, but rather as a philosophy of how to approach information management and decision-making tasks. The need for metadata education has expanded beyond the traditional short course or professional seminar to one necessitating the integration of metadata concepts throughout a comprehensive curriculum. The purpose of this article is to outline a pedagogic framework for such integration and offer accompanying strategies for increasing the scope of metadata education. As background, challenges faced in metadata education versus training are reviewed, followed by considerations for developing a metadata integration framework based on different course types, metadata topics, varying levels of detail, and student-centered learning designs. Two specific integration strategies are presented with a focus on desired learning outcomes associated with different end-user groups. Finally, opportunities are identified for linking metadata concepts to the existing National Center for Geographic Information and Analysis core curriculum for geographic information science.*

Introduction

Metadata is emerging as an increasingly important concept in the field of geographic information science (GIScience). Commonly defined as "data about data" (Milstead and Feldman 1999), metadata, in the GIScience context, refers specifically to descriptive information pertaining to geospatial data (Federal Geographic Data Committee 1997). Metadata concepts and implementation issues are a growing topic of GIScience research (Dutton 1996, Plewe 1997, Bowker 2000, Hunter and Masters 2000, Kennedy 2000, Norheim et al. 2000, Sengupta 2000, Tsou and Buttenfield 2000, Vert 2000, Spery et al. 2001). University researchers are dependent upon metadata to coordinate collaborative research efforts (Porter et al. 1997) and to support analysis (Meitner et al. 2001). Furthermore, in the professional arena, positions requiring metadata production skills are becoming more common, and geographic information system (GIS) software now incorporates metadata creation and management tools as core functionality. Both GIScience researchers in an academic environment as well as students and professionals training to meet GIS workforce requirements must be schooled in the principles and application of geospatial metadata. As a result, the need for metadata education has expanded beyond its traditional place in short professional workshops to a core requirement within GIScience curricula.

Why this demand for metadata knowledge and skills? In the academic research arena, metadata is a critical component of information science, one of the parent fields of GIScience (Milstead and Feldman 1999). Data discovery, information processing, and distributed information networking all require metadata in some form (Tsou and Buttenfield 2000, Eliot 2001). In the professional arena, the shift in the geospatial community from that of data producer to data consumer is largely responsible (Gaudet et al. 2001). Over the last decade, organizations have committed significant resources to the development of geospatial data and are now faced with vast data holdings but few mechanisms to leverage their investments through data retrieval and re-use (Guptill 1999). The tremendous growth in markets for data discovery, data warehousing, and decision support systems has resulted in greater awareness of the need for metadata to deal with all the complexity inherent in finding, organizing, and transforming data into information for daily consumption and decision making (Sherman 1997).

Education is key to building the metadata knowledge required to support decisions, as well as to establish data product requirements, to implement data quality processes, and to provide for interoperability among available data products. However, there appears to be little opportunity for students of GIScience and systems to build the metadata comprehension required to address these needs. Educators are often reluctant to create metadata as part of their own research, much less promote metadata within their classroom (Meitner et al. 2001). A recent ad hoc e-mail survey of University Consortium of Geographic Information Science (UCGIS) educators indicates that, while some GIS courses include metadata-related lectures and exercises, few have addressed the full range of metadata implementation issues fundamental to GIS (Wayne 2001). The current approaches to include metadata as an independent lecture topic reflect the professional GIS data development process in which metadata are generally created as an addendum effort. These methods tend to externalize the metadata from the data and can result in "data entropy," the loss of critical information about data over time (Michener 1998).

The purpose of this article is to address some of the obstacles related to metadata education and to outline a pedagogic framework for integrating concepts of metadata into existing GIScience curricula. Three interrelated strategies for such an integration are presented, based on research conducted by Berendsen and Hamerlinck (2000) and Wayne (2001). This research stemmed from current GIScience education priorities identified by UCGIS (Kemp and Wright 1997), which recognize that greater attention needs to be given to professional GIS education programs and the specific needs of this end-user group. Current GIScience curricula run the risk of being considered irrelevant by GIS practitioners because of their "one-size-fits-all" education model (University Consortium of Geographic Information Science 1997). Adjusting the GIScience curriculum to better support the educational needs of different users opens the door for opportunities to increase the scope of metadata education.

Metadata Education Versus Training

Similar challenges exist in geographic information systems and metadata education, in that both are accompanied by a profusion of technical terms and concepts as well as a prevalence of software tools to perform functions for data (or metadata) creation, management, and use. Studies have shown that in order to successfully teach GIS, it is important to find a balance between education (with concepts and principles) and training (acquiring skills for operating a specific software) (Piscedda 1994). One approach is theory-driven and lacks skills training; the other is technology-driven and lacks theory.

Since software trends are rapidly changing and unpredictable, it makes little sense to use them as a basis for curriculum design. Certainly there will always be a need for short courses and training workshops to keep up with software changes (Kemp 1991, Rogerson 1992), but metadata education, like GIS education, needs to develop beyond this type of limited and isolated training. Mastery of software does not necessarily equate with mastery of a subject (Marble 1998).

Studies on the introduction of new technologies within institutions offer valuable insight into the education versus training issue. Introduction of new technology is not just a technical matter (Campbell 1999). The successful introduction of new technologies or new methodologies requires the ability to overcome management and institutional obstacles, as well as the technical problems (Dale 1991). Training skills alone are not enough; potential users must understand how the skills relate to larger institutional concerns (Heywood and Petch 1991). For instance, recent studies have shown that organizations participating in metadata implementation programs recognize the value of metadata, but are reluctant to commit time to developing metadata skills because it would take too much time away from more important or necessary endeavors and responsibilities (Gelbman and Mathys 1999, Norheim et al. 2000). Gelbman and Mathys stressed that "any long-term approach to metadata implementation requires cooperation with educational institutions. Agencies with data access issues and metadata must establish contact with the respective departments at universities, colleges and technical schools to discuss measures to incorporate metadata into classroom material" (1999:15).

Metadata and The Evolving Field of Giscience

A 2001 survey of UCGIS members indicates that GIScience educators recognize the importance of metadata education but have little room in their already overburdened GIS courses to accommodate added lectures on metadata principles and practices. As a result, usually only the importance and value of metadata are addressed (Wayne 2001). Respondents also cited the complexity and transitional status of metadata standards in the United States and internationally, and the lack of supporting materials such as text/readings, lab exercises, and case studies as further impediments to including metadata education within their courses. The survey concluded that although metadata is fundamental to the "business case" perspective in which issues of data quality, data investments, data redundancy, and management efficiency prevail, from an academic perspective it is less significant than fundamental GIS concepts of topology, spatial representation, and associated technical and societal issues (Wayne 2001).

A major conclusion of a joint 1999 Federal Geographic Data Committee/UCGIS-sponsored workshop on metadata education was the need to integrate metadata throughout GIScience education, instead of as an individual lecture topic or component (Berendsen and Hamerlinck 2000). Integrating metadata throughout a GIS curriculum provides opportunity to tie in metadata with other important GIS issues and concepts. For instance, the foundational conceptual elements for a GIScience curriculum (such as data quality, projections, scale, and error propagation) are all topics that lead directly or indirectly to metadata elements. Forer and Unwin (1999) suggest that GIScience encompasses not only the technical and conceptual underpinnings of the use of geographic data, but also the social, legal, and ethical issues, which are arguably of greater importance and equal complexity. Many of these issues also tie into importance of metadata as a means of cataloging GIS data and a measure of the fitness-of-use of data for particular GIS applications. Educational units on these topics open the door to weave metadata into curricula, especially through exercises involving downloading, converting, transforming, and using different data sources together for the sake of analysis. By addressing different aspects of metadata at different intervals throughout a course, technical information overload can be minimized and the importance of metadata as it relates to multiple aspects of GIScience can be maximized. With this approach, metadata is no longer viewed as a task, but as an integral component of geospatial data, GIS applications, and elements of GIScience research.

A Framework for Metadata Education

A framework for integrating metadata education the GIScience curriculum may be constructed based on the following questions as modified from Unwin (1997):

- Should metadata be taught differently in different types of GIS-related courses?
- Where could metadata potentially be included in each type of course?
- At what level of detail should metadata be included (breadth vs. depth)?
- How should metadata be taught (content-centered vs. student-centered learning)?

Existing GIS-related course content and materials were reviewed in 1999-2000 to help answer these pedagogical questions (Berendsen and Hamerlinck 2000). The starting place for the review was the National Center for Geographic Information and Analysis (NCGIA) Core Curriculum for Geographic Information Systems (NCGIA 2000), NCGIA Core Curriculum for Technical Programs (NCGIA 1996), and online materials for the Geographer's Craft (Foote 1997). In addition, links to other online course materials are accessed through the University of Colorado's Virtual Geography Department and through UCGIS member institution profiles. Only course information and materials available online were included in the review as the project timeframe did not allow for contacting individual departments or faculty to request hard-copy materials. In many cases, this meant that information was incomplete or possibly not up to date. While the review was confined to materials catalogued by four Internet-only sources (NCGIA, Geographer's Craft, Virtual Geography Department, and UCGIS), it is representative of a broad range of different course types, including traditional university courses, GIS certificate courses, distance-learning courses, community college courses, and professional-type "short" courses.

Should Metadata be Taught Differently in Different Types of GIS-Related Courses?

A total of 145 courses were reviewed from 60 different educational institutions. The majority of these courses only had course outlines and syllabi available online for review; 34% also had online lecture materials available and 29% of the courses had laboratory exercises available. The courses were classified into 10 broad categories of course types:

- Geographic Information/Map Use
- Introduction to GIScience
- Advanced GIScience: Issues and Applications
- Advanced GIScience: Spatial Analysis and/or Technical Issues
- Advanced GIS: Software-Specific
- Courses in Related Disciplines using GIS for Applications
- Introduction to Cartography
- Introduction to Remote Sensing
- Global Positioning Systems
- Short Courses or Professional Courses

Of these, the most common course type was a basic "Introduction to GIS" or "Introduction to GIScience" course (46 examples). GIS applications/issues courses were the next most common (24 examples), followed by "Geographic Information/Map Use" courses (21 examples).

Each course type offers different opportunities for integrating metadata. Typically, the large amounts of conceptual information covered in introductory course limit the amount of time available for covering metadata, but its importance can be practically demonstrated in exercises and/or student projects. One advantage with the large number of topics addressed in introductory courses is that the relation of metadata to a great breadth of topics can be emphasized. Advanced courses typically focus in more detail on a few topic areas, providing more opportunity to cover metadata in depth than in introductory courses.

Where Could Metadata Potentially Be Included in Each Type of Course?

Of 145 reviewed courses, 48 (33%) made explicit reference to metadata either within the course outline or within course materials (Berendsen and Hamerlinck 2000). The number of courses including metadata is probably higher than this, as metadata could be addressed in the course without being explicitly identified in the course outline. Of the 48 courses that dealt with metadata, in 22 courses the subject was only briefly mentioned as part of a lecture, lab, or as an exam question ("describe what metadata is and five components of it"). In the other 26 classes, metadata was dealt with in more detail, usually within a laboratory exercise or as part of a class discussion. Most of the laboratory exercises dealt with finding appropriate data and downloading it off the Internet, requiring the ability to read and interpret metadata.

Many other course topics have the potential to make direct or indirect reference to metadata. Data quality is a major component of a complete metadata report, and this is a topic that was dealt with in 70% of the introductory courses reviewed, 52% of the geographic information/map use courses, 59% of related discipline courses, and 50% of GIS applications/issues courses. Metadata is also critical to finding and evaluating data sources, and this topic is also frequently covered in GIS-related courses. Other topics, such as standards, ethics, implementation issues, future trends in GIS, and decision making (e.g., GIS and decision support systems), do not appear as often but still offer additional means to integrate metadata as well as to help students realize the extensive, far-reaching implications of metadata.

At What Level of Detail Should Metadata be Included (Breadth vs. Depth)?

Within GIScience curriculum, balancing breadth and depth is one of the most difficult challenges (Unwin 1997). Breadth allows inclusion of a range of scientific topics, societal problems, managerial issues, and legal and ethical questions arising from use of GIS. Depth may lead to thorough examinations of only a few topics such as database management, interface programming, data structures, and statistical algorithms. As metadata is integrated within the GIScience curriculum, opportunities must be explored to expand beyond basic awareness to include both breadth (its relationship to standards, digital libraries, GIS implementation, and decision-support) and depth (its relationship to database principles, quantification and communication of error/uncertainty, and fitness-of-use). Integration of metadata into GIScience topics already covered in either breadth or depth provides the key to enhancing existing educational content without actually having to add or substitute a great deal of new information.

How Should Metadata Be Taught (Content-Centered vs. Student-Centered Learning)?

Research has shown that content is not the major influence in student learning. What students actually learn depends to a large extent on individual goals and learning processes (Unwin 1997). In the past, metadata education pedagogy has focused almost entirely on passing on content through lectures or readings, but lessons learned from GIS education show that content cannot be successfully learned and integrated into standard professional practice without employing a range of appropriate teaching methods (Jenkins 1991).

In contrast to a content-centered learning model, a student-centered learning model is based on examining individual student needs. Over the last 10 years, considerable work has been accomplished in developing flexible curriculum materials, teaching methods, and tools to foster this approach in GIScience education. Early examples of flexible curricula include the seminal NCGIA Core Curriculum for Geographic Information Systems (Kemp and Goodchild 1991) and Raper and Green's GISTutor (1992). Developing curricula with multiple interrelated paths for students with different needs and objectives is the goal of the UCGIS curricula (Marble 1999). Recently, efforts have shifted to World Wide Web–based resources such as the ESRI Virtual Campus and Pennsylvania State University's World Campus program.

These examples range from loosely structured course resources to detailed self-paced tutorials for learning-specific topics. For instance, instructors can pick and choose among the materials offered by the NCGIA Core Curriculum for Geographic Information Systems in order to develop courses suited specifically for their own students. The NCGIA Core Curriculum for Technical Programs (NCGIA 1996) provides specific learning outcomes based on a desired level: awareness, competency, or mastery. Learning outcomes allow course content to be specifically tailored for different levels of student audiences. ESRI's Virtual Campus was initially envisioned as a modular "knowledge base" of GIS concepts, examples, exercises, and test questions that can be retrieved and structured according to the wishes of a course author (Kemp et al. 1998). A modular design allows different disciplines to define their own emphases on the subject matter or to take different perspectives on the same subject matter (Langford et al. 1994). Links to modules in related subject networks are important because many of the ideas are transferable (Healey 1998). Such a modular, interoperable education model is applicable for integrating metadata education with GIScience. Course authors can select from a knowledge base of metadata concepts, examples, and exercises to integrate metadata to the level that best suits their course objectives or the specific-learning objectives of their students.

While modular-based learning materials may provide a student-centered environment, they do not necessarily increase students' retention. More effective learning strategies call upon students to produce rather than merely consume information (DiBiase 1996). Lessons learned from the GeographyCal project (Healey 1998) stress the importance of developing active learning experiences. Active learning requiring student involvement, discussion, decision-making, and problem solving has proved to be very successful (Meyers and Jones 1993, Keys-Matthews 1998). Laboratory work is also an important method of active inquiry. "Where lectures and readings at best familiarize students with concepts, exercises and discussions provide opportunities for students to develop some level of mastery by engaging the concepts experimentally" (DiBiase 1996:66). Such active learning activities are essential to support the content components of metadata education.

The review of existing course materials provided examples of exercises, which either already incorporate metadata or which are amenable for including metadata. With the availability of so much data on the Internet, there is no longer the need to provide students with "canned" data sets, and active learning is facilitated by requiring students to find, evaluate, download, import, transform, and use data that is available through clearinghouses and online project sites. Exercises are particularly useful if structured to drive home the point that without metadata the process of collecting and analyzing GIS data can be frustrating and inefficient at the least and inaccurate or inappropriate at the worst. Exercises structured to require students to use metadata within an active, decision-making, or problem-solving context are especially helpful.

Metadata Integration Strategies

In this section, we discuss basic content needed for metadata education, two different but related strategies for integrating metadata into curriculum, and finally a specific example of metadata integration in the NCGIA Core Curriculum for Geographic Information Systems.

Content for Metadata Education

Content or learning materials are the core of any education program and provide the foundation upon which different educational strategies can be based. In this section, we present content for metadata education organized into six modules, which can be mixed and matched for customized course development. The modules are:

1. What is metadata?
2. Why is metadata important?
3. Metadata content standards
4. Clearinghouse concepts
5. Using and implementing metadata
6. Examples of metadata

In addition to topics specific to metadata, material is also provided for relating metadata to other topics commonly found in GIScience courses, including:

- Coordinate systems/projections
- Scale
- Data types
- Database principles
- Data models
- Data sources
- Data quality
- Data creation/automation
- Spatial analysis
- GIS project design/implementation
- Decision making
- Ethical and legal issues
- Interoperability/standards
- Future/GIS trends
- Exercises/student projects

Using these topics as building blocks, educators can create a customized curriculum for their students' needs or build metadata into an already established curriculum. To promote student-centered learning, each topic includes the following components: learning outcomes; links to recommended preparatory topics; links to recommended complementary topics, vocabulary, and definitions; and suggested material which may include lecture notes, exercises, and/or discussion questions.

Strategies for Integrating Metadata into GIScience Curriculum

We have developed two strategies for educators and students to choose from, based on their specific learning goals. The first educational strategy is the more loosely structured, in which content is organized by learning outcome. This type of approach is especially well suited for distance, self-paced, or independent learning. Educators and/or students pick the desired learning outcomes, which provide links to specific content.

The second strategy is more structured, in which learning topics are organized by course types. Specific topics are recommended for integrating metadata into different types of traditional higher education courses, including introductory and advanced GIScience courses, map use courses, GIS for discipline-specific courses, and other course types including professional short courses.

Strategy #1: Learning Outcomes. The advantage of defining learning objectives or outcomes is that content can be specifically tailored for different "audiences" both in the academic and in the profession arena. For instance, academic students may range from undeclared freshman/sophomores seeking a general level of awareness to Geography majors requiring a broader exposure to GIScience topics, to GIScience majors requiring the greatest range of depth and breadth, to majors in other disciplines that utilize GIS technology or touch on some aspects of GIScience. Similarly, in the professional field, audiences may range from the "occasional user" to the "novice user," to the "informed user," to the highly technically skilled GIS analyst or programmer. To best represent the continuum of academic and professional audiences, learning objective categories were defined according to Heywood and Petch's five drivers for successful adoption of new technology in a business (1991):

1. Conviction of the effectiveness: ease of use/transition; improvement of quality and quantity of productivity;
2. Motivation to implement the technology and learn how to use, apply, improve and develop it;
3. Skills necessary for accomplishing various aspects the new technology, including new terminology and new structure;
4. Knowledge of topics to add breadth (relation of the technology to other technologies/fields, implications within the organizational or social structure) and depth (origin and basis for the technical/organizational structure; deconstruction of requirements); and
5. Experience that equates to skills plus knowledge: ability to find deficiencies or flaws in existing implementation; ability to adapt techniques to new or unique situations; ability to provide alternative strategies; ability to develop new applications and methods.

Learning outcomes for each of the topics were provided for Conviction, Motivation, Skills, and Knowledge (Experience being the outcome of Skills plus Knowledge). The five drivers noted by Heywood and Petch are best suited for this broad range of needs because they closely mirror the complexity of management and education problems faced in introducing a new "way of doing things" in an organization with already established procedures. Effective implementation is more than just training for skills or providing access to necessary knowledge, since metadata, like GIS itself, is more than a software program but is a whole philosophy of how to approach tasks. In the NCGIA Core Curriculum for Technical Programs (NCGIA 1996), learning outcomes are categorized by three different levels: awareness, competency, or mastery. However, a manager deciding whether employees should take time away from existing tasks to implement a new task needs more than just awareness or competency; material to provide conviction and motivation is also needed. A manager also needs enough knowledge to understand the implications and issues involved in the implementation of new tasks. Figure 1 provides an example of the learning outcome path a manager might take at the "motivation" level.

Strategy #2: Course Types. The review of course outlines and materials was used extensively to determine which topics are used most often in different course types and how existing learning material for these topics may be modified to include a greater emphasis on metadata. For each of the 10 course-type categories, a matrix was generated of course topics and learning outcome level ("conviction," "motivation," "skills," "knowledge"). All of these matrices and other materials are available at www.wygisc.uwyo.edu/metadata/education.html. In this section, extracts of this material are provided as illustration.

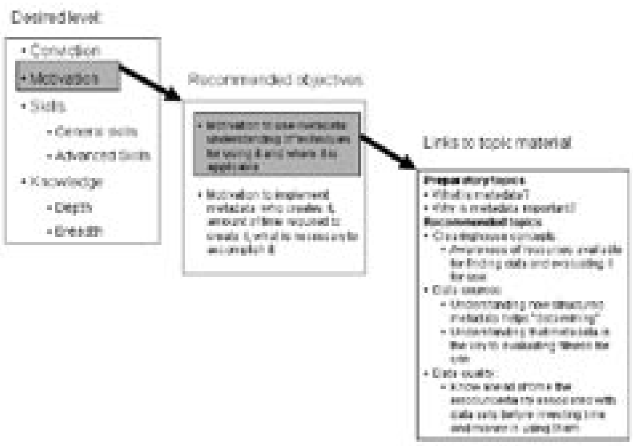

Figure 1. Example of a Learning Outcome Path

For each course topic and learning outcome level, a recommendation of primary or secondary priority is provided for integrating metadata. For instance, the results of the course review indicated that "GIS Implementation" is covered in 54% of Issues/Applications courses, but in only 9% of the classes in the Spatial Analysis category. Therefore, this topic ranks as primary recommendation for integrating metadata in an Issues/Applications course, while it would not be recommended at all in a Spatial Analysis course. However, in a Spatial Analysis course, primary recommendation for integrating metadata is given to other topics, such as Data Quality and Analysis, because of the importance of documenting the data used and steps taken in the analysis so that the results can be replicated. Table 1 shows a sample matrix for a Geographic Information/Map Use course, which deals primarily with maps and spatial data and usually only touches briefly on spatial analysis and related issues. Metadata may be integrated primarily at the "conviction" and "motivation" level, along with some basic skills pertaining to describing data (projection/scale, sources, and quality). In contrast, Table 2 shows a sample matrix for Advanced GIS/GIScience: Issues and Applications, which offers perhaps the greatest range of breadth and depth for integrating metadata, including more material targeted at the "knowledge" level.

Course Topics	Conviction	Motivation	Skills	Knowledge
Projection/scale	Primary	Secondary	Secondary	
Database principles				
Data types	Primary	Secondary		
Data models				
Data sources	Primary	Primary	Secondary	
Data quality	Primary	Primary	Secondary	
Data automation				
Spatial analysis				
GIS implementation				
Decision making				
Future/GIS trends				
Interoperability/standards				
Ethics/legal issues				
Student projects	Primary	Primary	Secondary	

Table 1. Matrix of recommendations for course topics and learning outcome levels for integrating metadata topics into a "Geographic Information/Map Use" course. "Primary" indicates the topic should be included with heavy emphasis at the indicated outcome level, "secondary" indicates the topic should be included, but receive less attention. Blank cells indicate where it is not necessarily beneficial to mention metadata related to the specific topic.

Course Topics	Conviction	Motivation	Skills	Knowledge
Projection/scale				
Database principles		Secondary		
Data types				
Data models				
Data sources	Primary	Primary	Primary	
Data quality	Primary	Primary	Primary	Primary
Data automation		Secondary	Secondary	
Spatial analysis		Secondary	Secondary	
GIS implementation	Secondary	Primary		
Decision making	Secondary	Secondary		Primary
Future/GIS trends		Secondary		Primary
Interoperability/standards		Secondary		Primary
Ethics/legal issues	Primary	Primary		
Student projects	Primary	Primary	Primary	

Table 2. Matrix of recommendations for course topics and learning outcome levels for integrating metadata into a "Advanced GIS/GIScience: Issues/ Applications" course. "Primary" indicates the topic should be included with heavy emphasis at the indicated outcome level, "secondary" indicates the topic should be included, but receive less attention. Blank cells indicate where it is not necessarily beneficial to mention metadata related to the specific topic.

Integrating Metadata into the NCGIA Curriculum

The National Center for Geographic Information and Analysis continues a slow but gradual revision of its GIS core curriculum to better emphasize the newly emerging field of GIScience. (http: //www.ncgia.ucsb.edu/giscc). The core curriculum is intended as a foundation for GIScience educators to build upon and enhance with their own insights and expertise. The status and flexibility of the curriculum provide a strong opportunity to incorporate disciplinary themes, new technologies, and emerging issues such as metadata. The working version of the core curriculum for GIScience is organized as a tree. A core perspective of GIScience serves as the root node, with the main branches addressing: (1) Fundamental Geographic Concepts, (2) Implementing Geographic Concepts, (3) Geographic Information Technology in Society, and (4) Application Areas and Case Studies. A review of each branch illustrates the manner in which concepts of metadata can be effectively integrated.

Fundamental Geographic Concepts. This branch of the Core Curriculum provides a basic explanation of how humans perceive and represent the world around them. Emphasis is placed on human cognition, cartographic representation, and digital constructs used to abstract and represent spatial relations and phenomena. Data representation is characterized as a series of choices about geographic extent, features selection, methods of data extraction/compilation, map graphics and projections, and the adoption of related standards. The key opportunity in this unit is to emphasize metadata as a means of documenting those choices, such that data consumers are aware of the inherent bias of the data representation and that software systems and users can effectively translate and display the data.

Implementing Geographic Concepts. The second branch of the NCGIA Core Curriculum focuses on the computing technologies and practical measures required to populate and utilize a GIS. Since implementation is fundamental to the "business case" perspective that best promotes the creation of metadata, the section provides the strongest opportunity to present metadata as a "best practice" throughout the data development and analysis process. Metadata can be promoted as a means of: (1) documenting data compilation sources, methods, and results; (2) locating needed data resources; (3) managing data resources; and (4) motivating self-assessments as to data accuracy, resolution, completeness, and consistency.

Geographic Information Technology in Society. The third branch of the core curriculum emphasizes the importance of designing geographic information systems that can be effectively applied to human inquiry and decision-making. To do so requires technicians capable of interpreting and meeting client needs as well as a technologically and geographically literate society capable of accessing, comprehending, and benefiting from applications. Metadata is a public information resource with strong capability to meet the human needs of both the GIS architect/manager and the public. It is a critical component in data distribution, from the National Spatial Data Infrastructure (NSDI) to universities and other organizations with Intranet and Internet geospatial data libraries (Goodchild 2000). Metadata is the communication medium between the data producer and consumer.

Application Areas and Case Studies. The fourth branch of the Core Curriculum provides an overview of GIS application areas and describes specific examples of GIS implementation. The case studies could be enhanced to provide application specific examples of quality metadata and discuss the effective use of metadata to locate data resources, understand data value/deficiencies, aid in the translation of data into geographic information systems, and manage data resources.

Conclusions

As early as 1996, metadata was recognized as one of several important elements lacking in the GIS curricula (Kemp and Frank 1996). Realization of the "real world" importance of metadata is still not adequately grasped by GIS students (Delaney and Bruce 2000). GIScience curricula needs to incorporate more than just a token mention of metadata. Furthermore, treating metadata as an isolated topic limits its important connection to a great depth and breadth of GIScience topics. By weaving metadata throughout GIScience curriculum, an important transition can be made from viewing metadata merely as a task to recognizing it as an integral element not only of geospatial data, but also of geographic information systems and science as a whole.

How is metadata an integral component of data? The elements of geospatial data have been described by the equation, "features = coordinates + topology + attributes + metadata" (Dutton 1996:253). In the same manner that budget data is the fiscal component of a data set or environmental data is the natural resource component of a data set, metadata is the descriptive component of a data set (Federal Government CIO Council's Interoperability Committee 1999). Metadata is that element of the data that describes content and structure, provides context, enables discovery, determines fitness-for-use, facilitates management, instills accountability, and limits liability.

Metadata should also be considered a fundamental, rather than ancillary, component of a GIS. GIS is traditionally defined as a system used for the input, storage, manipulation, and display of geographic data (Carter 1989). Metadata provides operational support to each of these GIS functions. By establishing metadata as a distinct component of GIS, metadata can be more fully utilized to identify, retrieve, assess, analyze, and manage geospatial data and projects. In many cases, rather than depending upon inefficient manipulation of very large data files, standardized metadata provides unrealized potential as an efficient mechanism for building queries, data models, and analyses to support a full spectrum of geospatial data development and management processes

The realization of metadata as an integral component of both geospatial data and GIS establishes a new perspective on metadata. This mirrors the new perspective on GIS education that developed in response to the limitations of technical training. A conceptual and functional linkage between GIS and the intellectual core of geography needed to be established to prevent the rigorous geographic theories behind the technology from being obscured (Sui 1995). Making this linkage has protected GIS from being perceived as a mere tool to be used by uninformed operators. Just as GIS is more than just a tool, metadata is more than just a task. Providing students with this new, intellectually-based perspective on metadata in their GIS education will benefit both the expanding field of GIScience and other related fields as a new generation of professionals enters the workforce with a thorough understanding of how metadata relates to geospatial data and GIS technology.

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