UC Santa Barbara
NCGIA Technical Reports

Title
Critical Issues in GIS-Based Educational Module Development: NCGIA's ArcView-based Color Your World Module (96-6)

Permalink
https://escholarship.org/uc/item/3cz893pk

Authors
Palladino, Steve
Van Zuyle, Paul

Publication Date
1996-07-01

NCGIA

National Center for
Geographic Information and Analysis

Critical Issues in GIS-Based Educational
Module Development

NCGIA's ArcView-based Color Your World Module

Steve Palladino
NCGIA Education Projects Manager

and

Paul Van Zuyle
Geography Department

University of California, Santa Barbara

Technical Report 96-6

July 1996

Critical Issues in GIS-Based Educational Module Development: NCGIA's ArcView-based *Color Your World* Module

Steve Palladino, NCGIA Education Projects Manager, and
Paul Van Zuyle, Geography Department, University of California Santa Barbara

This report seeks to provide a framework for Geographic Information System (GIS) based education module development. This framework of critical design and process issues draws from National Center for Geographic Information and Analysis (NCGIA) experience in creating GIS resources for K-12 schools.

The full potential of GIS in the K-12 classroom has not been met in part due to the limited availability of necessary support materials such as tutorials, exercises, datasets, background information on GIS and geographical data, and packaged approaches to using GIS software in learning. Now, however, GIS software is becoming easier to use as it adopts point-and-click icon and menu-based graphical user interfaces in step with broader trends in computing.   GIS tends to place heavy demands on computing power, but hardware in the schools is beginning to catch up to the software requirements. These positive trends have made creating materials that support teachers and students in their use of GIS more feasible and have encouraged various groups and individuals to begin creating these support tools. Some of these are modules built to amplify the learning potential of existing GIS software, in some cases hiding many of the complexities and revealing only those aspects of the software that are important to the specific educational objectives.

In this report the term "module" is used to refer to any set of materials designed to guide students through a learning objective as they work with a specific GIS package. The module will present selected problems, datasets, and paths for learning with the software. Module creation may include modifying the GIS software or linking it to other software. It is more than a tutorial teaching the use the software or a worksheet for answering a few questions with the software; rather, it is a formulated approach aimed at bringing down the barriers to effective classroom use of the GIS software package.

The modules investigated in this report are all based on the Environmental Systems Research Institute (ESRI) software package ArcView 2. The focus is primarily on a series of educational modules developed over the past two years by NCGIA. The three modules are: Color Your World, the introductory module, which uses a global level dataset; Light Up Your Nation which uses national level nighttime space imagery; and Know Your Neighborhood which uses local level street network and demographic data. The experience of creating these materials is compared to three other ArcView module development efforts. All together, these module development projects provide an indication of the commitment levels of human and computing resources necessary to create modules as well as the intellectual and technical considerations involved.

We begin with a bit of background on the issues related to ArcView-based module development. This includes a discussion of the critical issues, both in the design and in the actual development process. These issues are primarily explored in the context of Color Your World, but the other module development efforts are also reviewed. Finally, we present a discussion of lessons learned from all of these efforts.

Background

NCGIA and GIS Education
In 1991, as the National Center for Geographic Information and Analysis (NCGIA, a center for GIS research supported by the National Science Foundation and comprised of a consortium of the University of California, Santa Barbara; the State University of New York at Buffalo; and University of Maine) completed a comprehensive NCGIA Core Curriculum in GIS (Goodchild and Kemp, 1990) and other resources to support university GIS educators, it became apparent that GIS might have a role in the pre-college classroom. A study in 1992 and 1993 of current activities and potentials for GIS use in the classroom found that GIS was especially attractive for group work and problem solving activities, but at that point had a very limited presence (Palladino, 1994). However, the study noted that as personal computing power increased with corresponding falls in prices, schools were becoming interested in or actively involved with GIS.

GIS in the schools
Palladino's 1994 study also described some of the early efforts to use GIS in the classroom. Much of this early use was by pioneering teachers who were endowed with excellent computer facilities, advanced students, and flexible curricula (e.g., magnet and private schools). In the past few years, however, GIS has been finding its way into a broader cross-section of schools. In addition to the NCGIA study, a number of other sources have documented GIS use in the classroom. These include:

Palm Beach School District which has developed a GIS curriculum (Ramirez, 1995);

Oregon Seaside High School's GIS-based Coastal Studies and Technology Center which has been recognized by the President of the United States as a model program (ESRI, 1995a);

Thomas Jefferson High School for Science and Technology's use of GIS in its geoscience program to complete projects such as building a digital elevation model of the campus (Fazio and Keranen, 1995); and

a group of schools featured on a video introducing GIS use in the schools (ESRI, 1995b).

The Internet World Wide Web is also becoming an important source for information on use of GIS in the schools.[1]

ArcView GIS
A number of available GIS packages are used in the schools (e.g., IDRISI, Maptitude, SPANS, MapGraphix, MapInfo, Intergraph MGE). Based on NCGIA observations, however, the most common software package found in the schools probably is ESRI's ArcView. This is in large part

---

[1]Following are some World Wide Web home pages containing information on GIS in the schools that were current at the time of writing:
ESRI's K-12 program (http://www.esri.com/resources/k-12/k-12.html)
Thomas Jefferson High School for Science and Technology Geoscience Department
  (http://earth.tjhsst.edu)
EdGIS (http://hub.terc.edu/terc/edgis/edgis.html)
IDRISI (http://www.idrisi.clarku.edu)
NCGIA's Secondary Education Project http://www.ncgia.ucsb.edu/education/ed.html)

due to an aggressive and generous campaign by the company to get its software into classrooms around the nation. This has been aided by the company's Adopt-a-School program and either outright gifts or large discounts on the software.

As exposure to ArcView among teachers has increased, there have been a number of efforts on the part of teachers, GIS practitioners, and university faculty and students to create ArcView-based learning materials for K-12 students. NCGIA with its on-going study of the use of GIS in the classroom (the Secondary Education Project), has undertaken a number of efforts to develop GIS materials for the schools. The most recent effort has been the development of ArcView-based educational modules discussed in detail later in this report. NCGIA has also just recently redesigned its undergraduate level GIS lab materials using ArcView as one of its GIS learning tools (Taylor, Fletcher, and Kemp, 1996). These labs, although created for an older audience, could be adapted for use in the secondary schools. Of the other groups and, in some cases, individual teachers developing GIS materials, many have selected ArcView as the core software for their learning modules. Some are using the Avenue programming language which comes with ArcView 2 to write scripts (sets of Avenue computer code which modify the graphical user interface and control the use of ArcView's tools) in order to guide student learning.
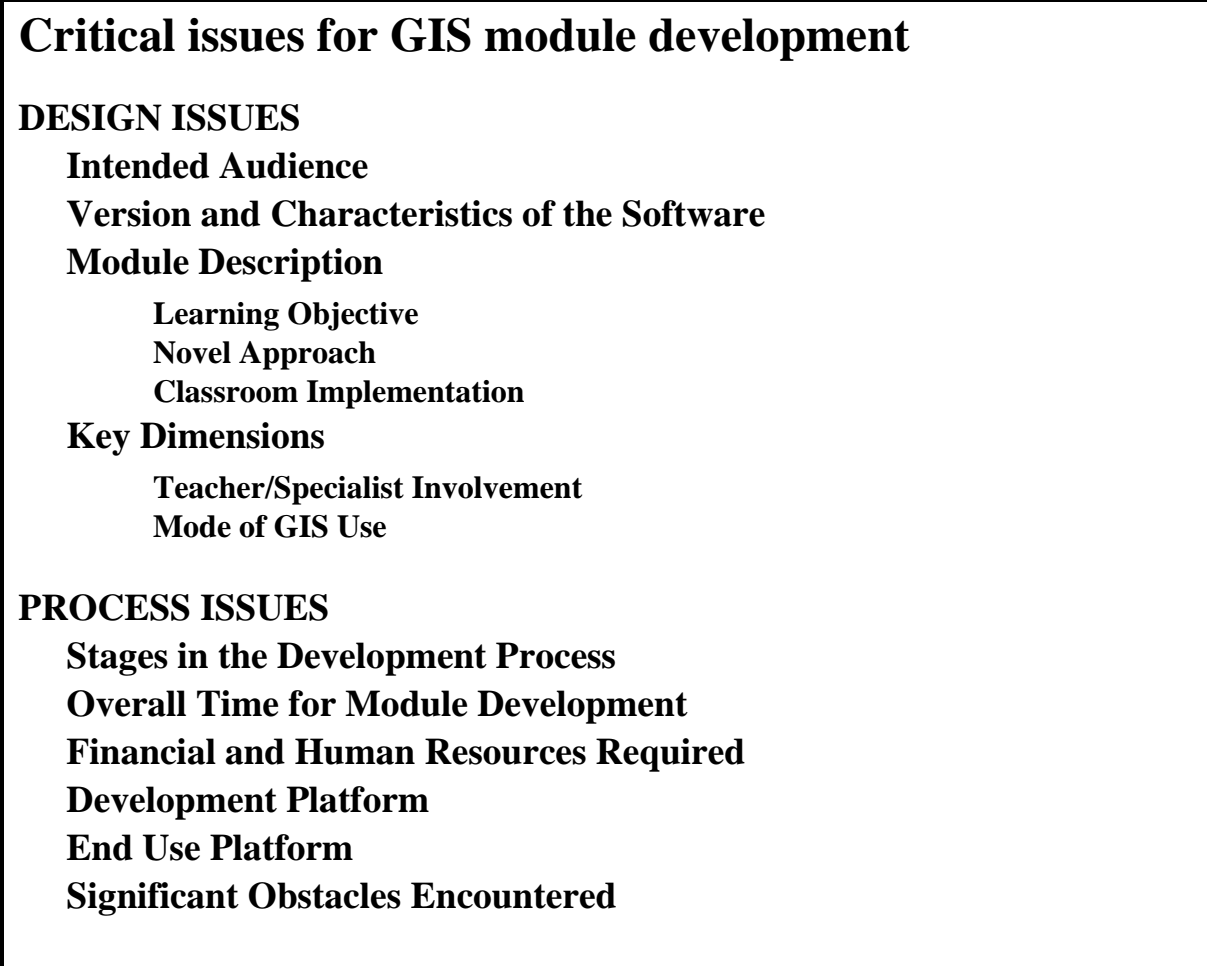
ArcView provides the user with tools to create and display *views* which are essentially maps built from data organized by theme (e.g., major roads, soil types, property zoning classifications, population density), *tables* which list the attributes of the map features available for display in a view, and *charts* which allow for bivariate comparisons of the tabular data. ArcView also has the ability to create links to other digital documents such as photographs and text. The combination of tabular data and the accompanying views and charts is known as a *project*. The software also provides tools for managing interaction between the different elements of a project, for incorporating new data, and for performing spatial analysis on the data. With all these tools and different project elements, working with ArcView can become too complicated for the instructional purposes of the K-12 teacher or may take away from productive on-task activities by students. This has led to efforts by NCGIA and others to simplify and focus the use of ArcView.

Module Development Issues

Although ArcView provides access to some of the power of GIS which may be especially useful for learning in the schools, developing ArcView projects, Avenue scripts, or complete ArcView learning modules presents a number of challenges. The issues relating to the development of ArcView-based learning materials are outlined below and explored in the context of NCGIA and other development efforts, in order to provide a template for future module creation efforts. In this report we do not attempt to also provide a framework for quality evaluation.

The relevant issues in module development can be grouped into two broad categories: Design Issues and Process Issues (Figure 1). Design issues are conceptual--they relate to the characteristics of the module. Process issues are practical--they refer to "nuts-and-bolts" aspects of creating the module. While all of these issues can be applied broadly to module development efforts with other GIS software, here the focus is primarily on ArcView.

Figure 1

Critical issues for GIS module development

DESIGN ISSUES

Intended Audience
Version and Characteristics of the Software
Module Description
Learning Objective
Novel Approach
Classroom Implementation
Key Dimensions
Teacher/Specialist Involvement
Mode of GIS Use

PROCESS ISSUES

Stages in the Development Process
Overall Time for Module Development
Financial and Human Resources Required
Development Platform
End Use Platform
Significant Obstacles Encountered

DESIGN ISSUES

Intended Audience
One of the first issues to decide when developing materials for education is the target ages for use of the particular module. The most active use of ArcView in schools is likely to be at the secondary school level; however, there are examples of elementary school students effectively using the software (ESRI, 1994). If the audience is pre-collegiate, a module may be specifically designed for the selected age group; however, in some cases, modules designed for university education may be modified to serve the needs of a younger audience.

Software Characteristics
The characteristics of the development software must be also be considered when creating GIS modules. This evaluation of potential software can be iterative beginning with the goals of the module, then a search for appropriate software, followed be an adjustment of the goals based on the capabilities of the selected software. This critical issue includes not only deciding which software to use, but also which version, since in some cases, schools will not be prepared to use the most up-to-date version. In the process of selecting the GIS that will serve as the core of the module, it is important to examine its functionality and to assess the likelihood that it will be adopted by schools.

The modules that have been or are currently being produced using ArcView either are built on the original version, ArcView 1, or the current version, ArcView 2. ArcView 1 has been distributed free since the release of ArcView 2.[2]   Many of the schools with ArcView still have the original version which does not allow for modifications via Avenue scripts and also has more limited options with regards to data input, linking, and processing. In this version, teachers or others can produce modules that are essentially pre-designed projects which take students directly to the mix of tables and views of the data that will support specific learning objectives. For example, a teacher may create a project using key development-level indicators (e.g., population growth rate, GNP, infant mortality) for the countries of the world. Pre-designed views may present thematic maps of this data for students to use in formulating questions about the different development levels of countries. Although this project is pre-formulated, ArcView allows the students to explore beyond the current views and create new presentations of the data which may answer their questions. This also means that students working independently could also get lost in the many dialog boxes and setting options provided by the software.

Although ArcView 1 may be the most common version in the schools, many schools have ArcView 2 and more may upgrade in the future. Since ArcView 2 can be modified with the use of Avenue scripts, modules can be created that more adequately guide students in their use of ArcView in order to achieve learning objectives that would not be possible with the original version. Avenue allows the designer of the learning module to modify and control the graphical user interface, to activate and modify windows, to present critical instructions or queries to students at key points, and to activate external programs. Because of this greater facility for data investigation and interface modification, NCGIA has used ArcView 2 in its development efforts. However, the problems caused by different versions of a development platform like ArcView are not likely to diminish in the future--we anticipate that similar issues will arise when the next version of ArcView, or its successor, arrives in the not too distant future.

Module Description
A core issue in any educational material development effort is the content of the material. Concomitant factors such as learning objective, novelty, and practical application, are expressed in these teacher questions: *What will it accomplish?*, *What does it do that is special?*, and *How will I use it in my classroom?*

Learning Objective An important distinction to make when discussing GIS use in education is the goal of the module. Is the module designed to teach GIS concepts, provide a tutorial on the use of the specific software package, demonstrate spatial analysis principles, or to elucidate traditional subject area content (e.g., geography)? We have found that the latter two are of greatest interest to the pre-collegiate instructor; however, there may be some interest in or need to also accomplish the former two. This provides one of the critical measures of an ArcView module--what does it teach, GIS theory, software use, spatial analysis, or other subject content?

Novel Approach GIS software and ArcView in particular present many opportunities for innovation. The novel approach may be in the way ArcView 2 is programmed with Avenue, in the linkage to external software programs, in the mix of data accessed in the module, in the type of spatial problem solving attempted, or in a number of other approaches possible with this particular software. This is the big draw of GIS software; it is more powerful and flexible than electronic

---

[2]ArcView 1.0 is available as a no-charge, royalty-free, licensed product from ESRI via ftp. Information on ArcView 1.0 and download procedure can be found at http://www.esri.com/free/arcview1/arcview1.html

atlases and "canned" geographic software currently available. But the key issue for schools may be to find a balance between the power and flexibility of GIS on the one hand, and the need for a short learning curve and clear learning objectives on the other.

Classroom Implementation ArcView or any GIS software may be implemented in a number of teaching configurations and unit types. One example is the use of GIS at home by the instructor to prepare maps for use in the classroom. These maps may be projected on a screen for the whole group of students, given to individuals, or used as the basis of cooperative learning activities. GIS modules, however, assume actual use of GIS software by students. In some cases, there may be only one GIS-capable computer in a classroom. This situation may call for the teacher to lead discussion as the class works through the module with the screen contents displayed on a large monitor, such as a television, or with a projection device. Other single-computer classrooms may opt for revolving use of GIS software on the machine by teams. Classes with access to multiple machines capable of running the software can take advantage of modules designed for individual, partner, or group work. The duration of activities outlined in the module is also a critical consideration. The module may be designed to be completed in a class period or may be the subject of a long-term group project. It may be a series of discussion openers that could anchor a whole unit or course on geography, environmental studies, biology, earth science, or spatial problem solving. Since there are so many possibilities, this is a critical element to include early in the module design stage.

For ArcView, its use in the classroom may take many of these forms, but initially students will need concentrated exposure with heavy guidance in order to be successful with the software. With training and experience, they may be able to work more independently. This is different from many of the current educational software products which utilize common interfaces and hypermedia-based links to facilitate ease of use. A common goal of ArcView module development efforts is to make access to the power of ArcView more intuitive.

Key Dimensions
There are two critical dimensions to examine in ArcView module development efforts: *Who is doing the development?* and *How much control does the user have over the software?*

Teacher/Specialist Involvement This dimension describes the involvement of the end user (teacher) in the development process. On one end of the spectrum are modules created completely by the teacher who plans to use them in his or her classroom and to offer them to other teachers for their use. At the other end of the spectrum are modules entirely put together by specialists (university professors and students, GIS users in the community, software or curriculum design experts). In the range between these two poles are modules designed in part by teachers and by specialists (Figure 2).
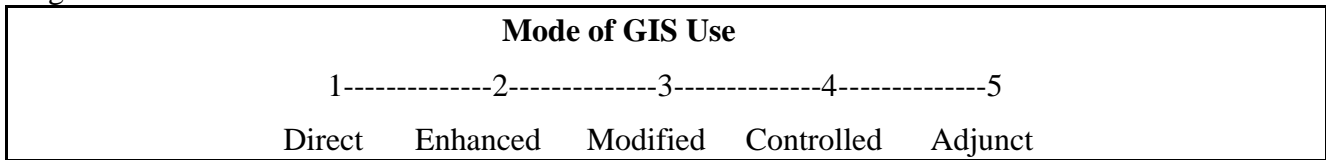
Figure 2

Teacher/Specialist Involvement		
1--------------2--------------3--------------4--------------5		
100%	50%-50%	100%
Teacher Designed		Specialist Designed
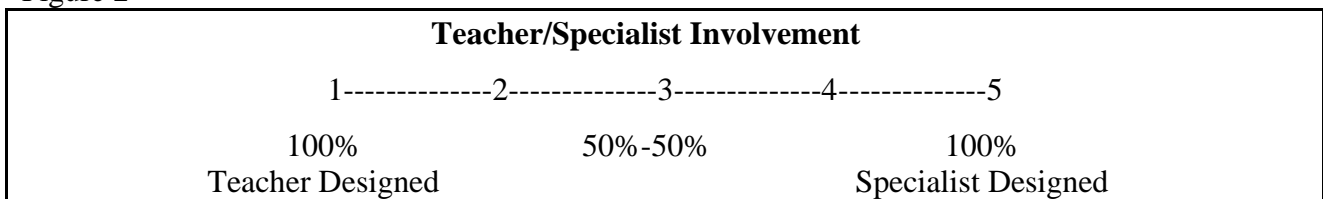
Mode of ArcView Use The second key dimension is that of user control and interface modification (Figure 3). This is concerned with the manner in which ArcView has been modified in order to help the student achieve the learning objectives.

Figure 3

Mode of GIS Use
1--------------2--------------3-------------4--------------5
Direct   Enhanced   Modified   Controlled   Adjunct

On one side, the student has complete access to all of the tools of ArcView (i.e., no modifications of the user interface through Avenue scripts or other software tools). In this "Direct Use" mode, the student may be expected to follow a specific path through an ArcView project outlined on the written support materials of the module or may be allowed a more open ended exploration of the data with ArcView.

A second category might be labeled "Enhanced Use" in which the user is guided by ArcView help text or simple scripts that respond to the student actions. There would be very little, if any, modification of the user interface (e.g., a "go back" or "explain" button might be added or a few ArcView tools may be hidden).

A third category can be labeled "Modified Use". Here there is a very purposeful modification of the user interface to simplify or guide the student use of ArcView to achieve the learning objective. The button and tool bars may be significantly modified to reflect the aims of the module. Scripts control much of the user interaction with ArcView, though the user can choose to use some of ArcView's tools on his or her own initiative.

A fourth level is that of "Controlled Use" in which the user is guided through an analysis by a fully scripted module. The user interface may be highly modified to help the user focus on the task at hand and not be distracted by the bells and whistles of ArcView. This mode gives the user very little or no access to the tools of ArcView except when they are needed to complete actions dictated by the module.

A final mode of ArcView use in a module might be "Adjunct Use" with respect to another software package or to a unique computer interface programmed to achieve the module goals. The focus isn't directly on ArcView as the primary base for learning, but as just one part of the module. The functionality of ArcView that is accessed may be highly limited.

Although this dimension is not strictly linear, the goal of this measure is to attempt to get a sense of access and style of use. On one extreme the user finds ArcView with no modification and must rely on text explanation of the process required to complete the module. On the other extreme, ArcView operates in the background as a source of inputs to help the user complete the task set out in the module. Another way to view this dimension is from a software coding perspective, from unengineered to highly engineered.

PROCESS ISSUES

In addition to these conceptual design issues, there are the practical issues of the actual module development process. These issues provide a sense of the level of commitment the module development requires in terms of time, money, manpower, scheduling, and computing resources. This category also includes the technical and practical challenges faced along the way.

Stages and Overall Time in the Development Process
Although these both of these issues may exhibit some similarity between module development projects, they are specific to each ArcView module development project and can vary considerably, thus can not be easily framed as dimensions or classes as some of the design issues were above. Some general stages do exist. They include design, writing/coding a draft, internal testing and revision, external testing and final revision, and dissemination.

Financial and Human Resources
The resources needed to develop education modules vary widely, and include the cost of staff salaries (total person-hours), staff training, and equipment purchases necessary for the completion of planned module. In the case of using ArcView as the base of module development, there is a need either to begin with experienced users as module developers or to provide time and resources for the development staff to become proficient with the software. With ArcView 2 this may mean practice with Avenue for which some background in computer programming is very helpful. Depending on the scope of the project, gaining software proficiency might be a fairly minor expense or may consume much of the project funds. GIS software is usually more difficult to master than most education software or even than common business software.

Development Platform
This issue includes the hardware configuration and additional software required to create the module. The minimum requirements for ArcView 2 are stated by ESRI as a multimedia PC, 386/25MHz machine with 8MB RAM, a CD-ROM drive, and Windows 3.1. Experience shows, however, that a more powerful computer is necessary to run the program at a speed that allows it to be sufficiently interactive. ESRI recommends a 486/75MHz machine with 16 MB RAM. ArcView is also available on Macintosh and various workstation-based operating systems. Thus, the development platform can also vary significantly between module development projects.

End Use Platform
Module development must be carried out with respect to a specific computer configuration found in schools. The module may be developed to work on older computers that are common in the schools or may be targeted to higher capability machines that may only be present in a few schools. Some of the current GIS software options for the schools, including ArcView 2, require more powerful personal computers than are found in the average classroom. ArcView module development relies on schools or teachers that are progressive in terms of acquiring newer computer hardware or on teachers that have invested energy and in some cases personal financial resources to provide more advanced computing in their classrooms.

Significant Obstacles Encountered
The final issue of this framework is open ended, in that it can encompass any of the challenges encountered in a particular module development project. These range from technical difficulties in programming the module to resistance on the part of some computer phobic teachers to do module testing. By examining these difficulties, those considering module development can anticipate some of the challenges they may face.

Lessons from NCGIA ArcView-based module development

The NCGIA Secondary Education Project (SEP) ArcView-based module development effort provides an opportunity to examine these critical issues in context. Here we will focus primarily on the *Color Your World* (CYW) module which was completed in early 1995. In 1993, after completing a first phase of SEP activities in which the role of GIS in the schools was explored (Palladino, 1994), SEP began to seek ways to empower teachers with support materials for their classroom use of GIS. This resulted in a set of resources from our GIS workshops for teachers and an *African Data Viewer* (Palladino, 1993a and 1993b). The *African Data Viewer* combined a series of thematic images of the African continent with the display modules of IDRISI, a rasterÐbased GIS software package.[3] The purpose of the Viewer was to provide teachers with a simple tool that would allow them to introduce digital spatial data into the classroom. Although the Viewer provides the look and feel of a GIS, it does not include the processing capabilities. Students can use it to investigate the data, but not to synthesize new information.

The SEP was looking for an opportunity to go to the next step--to create modules that would more fully utilize the power of GIS. This could have been accomplished with a number of GIS packages, but it made the most sense to begin our work with the software that had the greatest exposure in the schools, ArcView. ArcView's vector-based data structure and processing also provided a new direction for SEP materials. Most of the funding for this SEP ArcView-based module development was part of a gift from ESRI for NCGIA research projects. The primary goal of this module development effort was to use the power of GIS, not to focus on how the software worked or on the details of GIS functionality, but rather to investigate spatial data in ways which may not be accomplished with any other type of software or resource. However, a secondary goal was to use the student's interest in the geographic content of this module to help build familiarity with GIS tools and the manner in which ArcView organizes and presents data.

DESIGN ISSUES - Color Your World

Intended Audience and Software Characteristics
Our target audience is primarily high school students, but the modules are designed so they might also be used in undergraduate or junior high school courses. We chose to develop our modules with ArcView 2 rather than ArcView 1 for the greater design opportunities it provided with its Avenue scripting language and due to the fact that the company would be encouraging schools to work with that version in the future.

---

[3]The IDRISI project, based at the Clark University Graduate School of Geography, generously allowed the NCGIA to use the display modules: COLOR, LIST, ORTHO, ENVIRON, and IDIRISI. This gave the Viewer the capability of displaying IDRISI format images with the option of superimposing a vector file on top of the raster image and of draping images over a 3-D representation. The *African Data Viewer* is DOS-based and runs on Intel x86 processors.

Module Description
Working from these general criteria, we were presented with an opportunity to explore how the capabilities of ArcView might elucidate a variety of topics or solve a number of problems. Initially we considered drawing the module topics from the human geography domain since there were pending efforts by other groups to use ArcView to explore physical data. After a number of iterations, we established a plan to develop three modules--one focused on the global scale (CYW), one at the national scale, and one at the local scale. The initial module would ease students into the use of ArcView as a learning tool. The following two modules would tackle more conceptually challenging issues.

We wanted students to begin to use ArcView without being distracted by the mechanics of operating the software. This introductory module, Color Your World, adopts a game-like approach which uses the structure of ArcView: views, tables, charts, and links to photographs. It takes away the barrier of "how to use" the software, while subtly enabling the user to become comfortable with the manner in which ArcView manages spatial data. This approach was highly influenced by the GeoSim modules developed by a team at VPI (Virginia Polytechnic Institute and State University; Carstensen et al., 1993). In their simulations, there is very little distraction caused by a need to operate the software; the simulations are straightforward and compelling. Simple actions by the user are immediately followed by results. This is in contrast to GIS software in which it may take a number of steps to create obvious, visual results. Thus, in CYW, we automate data management and linking and free up the student to explore the data. In the case of CYW, most of the data is drawn from the sample data that comes with ArcView, but we supplemented that data with other country level data such as number of McDonalds restaurants, number of cigarettes produced, and number of water buffalo.

In Color Your World, the student is presented sequentially with three types of tasks (called rounds) in which they investigate data about the countries of the world. First the student is challenged to identify countries based on clues: a view of the country and its neighbors without the names; a table of demographic, economic, and other data about the country; or with a photograph of some cultural or physical feature in the country (Figure 4 [this is an screen image of CYW]). Points are accrued for correctly identifying the country from a randomly generated list of countries. Points are subtracted for accessing clues and for incorrect answers. A second round presents students with a titleless global thematic map spontaneously generated by an Avenue script from one of the categories in the database. The student uses the classification scheme and the range of values presented in the legend and the pattern observed on the world map to select the correct theme from another randomly generated list. A final "bonus" round has the students use the ArcView selection tool to pick the five countries with the highest values for another theme again randomly pulled from the database. As the student selects countries, their values are interactively displayed on a bar chart generated by the software. When the student is satisfied that he or she has identified the top five, he or she selects the answer button. CYW then presents the score for the current game and the student can chose to start a new game, perhaps this time at the intermediate or advanced level. These higher levels increase the difficulty of the game and also require the users to begin to "drive" the software themselves. At these levels, students can choose to access some of the ArcView tools not specifically used in the module. This allows them to circumvent the limitations imposed by the game, which on the surface may appear to be "cheating", but in effect creates a situation in which the "hacker" is actually learning more about the software.

Learning Objective The structure of CYW outlined above provides an indication of the overall learning objectives for this initial module. The learning activities in this module are most heavily weighted towards students' understanding of patterns (global thematic maps) and details (political border outlines, features seen in photographs, and demographic and other characteristics of countries). In a final round they are asked to synthesize information and build on their experience with thematic maps and tabular data from the first two rounds. Thus this module could be grouped with others that seek to teach subject (geography) concepts and also a limited amount of spatial analysis (patterns and identification of countries based on regional context). It also achieves exposure to the mechanics of the software, but doesn't specifically focus on learning to use the software nor on understanding GIS theory.

Novel Approach On the surface, Color Your World, may appear to be similar to games like Where in the World is Carmen SanDiego or to those that are part of some electronic atlases. CYW, however, is dynamic. Since all rounds are generated randomly from the database, there is a very low probability that a user will encounter an identical set of countries and thematic maps as they work through the module multiple times. Also distinguishing CYW from these other games and even GeoSim is the fact that it clearly presents the face of a GIS software package to the user and even allows the user to access some of the data manipulation and processing tools. It demonstrates one manner in which GIS may be used to teach geography and spatial analysis.

Classroom Implementation Since CYW is game-like in its structure, it may be used as an entertaining introductory activity to a unit on world geography, thematic mapping, global economic disparities, or a number of other topics. The game takes approximately 15 minutes to play, but this figure can vary greatly with the level of data exploration and pattern examination encouraged by the instructor. The game can be repeated as often as the teacher or student desires since new countries will be selected for every game. One general mode of use would be for small groups of students to concurrently use CYW in a computer lab or classroom with multiple computers for one class period. CYW could also be used in turns for part of a class period by groups of students. Another possible use would be as an optional activity for individual students who finish another assignment early. Since CYW was designed to introduce the use of GIS data and software to students, CYW may serve as a warm up activity for a more intensive use of ArcView or other GIS software.

Key Dimensions
Teacher/Specialist Involvement. Although the project manager and one of the two graduate students working on CYW are former high school teachers, CYW is essentially closer to the specialist-designed end of the spectrum shown in Figure 1, since all of the project staff are heavily involved with GIS. As the module was being developed, there was some limited testing with teachers and students. Overall, though, this module was not designed with dedicated support from a current school teacher.

Mode of ArcView Use CYW would fall close to the "Controlled Use" category of Figure 3. This is especially true at the "beginner" level of the game. The "intermediate" and "advanced" levels allow more access to ArcView's tools and thus would tend more toward "Modified Use."

PROCESS ISSUES - Color Your World

Stages and Overall Time in the Development Process
Color Your World required about one year to complete (early 1994 to early 1995). The project began with the project manager and other involved parties outlining the modules and arranging the acquisition of software and hardware. During these months, two geography graduate students with ArcView, classroom instruction, and some programming experience were selected to work on the project. In our later module development efforts, this stage was much shorter since we were able to build on conceptual work already done and had the work team in place. A second stage was data collection, equipment set up, ArcView and Avenue training (provided at the ESRI headquarters by ESRI trainers), and more extensive module outlining. The third stage, which occupied most of the summer and fall, was the heavy development stage in which the module was put together and initially tested and revised. In the last stage, dissemination, the module received final pre-distribution modifications, the Windows Help files were converted to a paper document, and the module was made available from NCGIA on 3.5" disk and via Internet ftp.[4]

Financial and Human Resources
The two graduate students who worked on the project were employed at half time for three quarters of a year. Adding in the time spent by the project manager, the whole project required nearly one man-year of effort plus the cost of a computer. The total cost for CYW development included a considerable start up cost in terms of training, design issues, and purchasing a computer. Since we chose to significantly modify the interface and use of the software, it was essential that the development staff had some programming background and had access to and time for Avenue training. As we are finishing the development of the two follow-up modules, it appears that combined cost for these two will be approximately equal to what was spent on CYW reflecting the benefit from investment in training, hardware, and experience in the first module.

Development and End-Use Platforms
We chose a 16 MB RAM 486/100MHz machine with a CD-ROM drive and the Windows operating system as the development platform. ArcView 2 is a memory-hungry and power intensive program, thus we did not want to opt for the lower speed 386 machines that were still common at the beginning of 1994. We have modified CYW to work on a UNIX-based workstation for in-house use, but have not made it available in that format since these platforms are rarely found in the schools.

Significant Obstacles Encountered
As with many custom programming and multimedia efforts, a great deal of time was required to produce a small product. It is particularly easy to underestimate the time required for debugging and revision. While this project benefited from different perspectives of team members, it also required careful coordination between individual efforts. Unlike other traditional publication environments such as book publishing, there is little common knowledge on which to draw for guidance. The result was frequent mismatches between ideas and execution which required

---

[4]Color Your World can be ordered from the NCGIA Publications Office, Geography Department, University of California, Santa Barbara, CA 93106-4060. It is also known as Technical Report 95-5, costs $4, and comes with a diskette and manual. The publications office can also be reached by phone: 805-893-8224, fax: 805-893-8617, and email: ncgiapub@ncgia.ucsb.edu. The module can also be down loaded via ftp from ftp.ncgia.ucsb.edu/pub/Publications/tech_reports/95/95-5

correction. As well as creating a product, the team had to devise a process for designing and producing the module.

There are some other technical issues related to developing a resource such as Color Your World. CYW is run entirely by scripts written in Avenue. Avenue has a cumbersome number of commands, but each can carry out complex operations. Without some instruction or prior programming experience, the learning curve for Avenue is a steep climb. For Color Your World, NCGIA developed a custom help system along with the Avenue scripts that control the game. The help system follows the Microsoft Windows help file format, where hypertext links allow navigation through the document and direct access to keywords. While the CYW program was designed to be self-explanatory, the help system is intended as a supplement and resource for teachers and users. Help system authoring tools for Windows are widely available, and a shareware program in conjunction with Microsoft Word was used to generate the compiled Help documents.

An additional possibility available with ArcView is the connection of the Help system to ArcView through a programmed link (dll). While this feature was not exploited in Color Your World, using the Help system text to run ArcView commands has been extensively exploited in the subsequent NCGIA educational modules.

Subsequent NCGIA ArcView Modules
The experience from CYW was extended in 1995 to the development of two additional modules designed to build on the exposure to ArcView and GIS provided by CYW. Many of the issues explored above for CYW are the same for these modules. The same graduate students are using the same computer and ArcView 2 to create modules for high school students that emphasize traditional content exploration and spatial analysis learning objectives, rather than focusing on learning GIS or the software package. Again, the bulk of the development is being carried out by these Avenue specialists rather than by teachers. The mode of use in this case could be classified as Modified (Figure 3) since the user now has greater access to the software, but is still guided by help boxes and scripts. Each of these modules will require approximately one year to create by one graduate student working at approximately 25% time a month. Some additional resources were required for project management and computer supplies.

The first of these modules, Light up Your Nation, takes advantage of ArcView 2's ability to display both raster and vector data as an aid to student exploration of nighttime Defense Meteorological Satellite Program (DMSP) imagery and ArcView ArcUSA sample data. The module leads the student on an investigation of the reasons for light patterns on DMSP images of various regions of the world, then focuses on a comparison of US nighttime imagery and US population. Students use the software to zoom in to their home area and investigate its characteristics, especially the correlation of the DMSP imagery with the population distribution. Development of this module also required processing the DMSP data in a UNIX workstation which provided a number of data conversion and registration challenges.

The final module is Know Your Neighborhood, an exploration of 1990 Census data. This module is designed to be used with the Census data set packaged by Wessex, Inc. It also makes extensive use of a hypertext help system both as a tutorial and as a means of interfacing with ArcView. The goal was for students to interact with a dataset that was both immediately meaningful ("that's my street!") and modifiable so that students would own the data. The module begins with a global view of the Earth and a demonstration of the latitude/longitude coordinate system. To give students a sense of scale differences, they zoom in from a view of the Earth to a view of Washington, DC.

The capital is used as an example for locating map information, geocoding, and exploring census data through prepared thematic maps. Students are then led through the process of extracting census data for their own neighborhoods from the Wessex CD-ROMs. With the skills gained by practice on the map of Washington, they are encouraged to add information to a street map of their neighborhood, locate addresses, and perform simple analyses.

NCGIA may develop additional modules in the future. A related effort mentioned previously is the revision of the NCGIA lab exercises for GIS courses originally prepared in 1990 (Dodson, 1991). The revised exercises use ArcView 2 instead of PC Arc/Info, ESRI's full featured GIS, which was used in the earlier exercise. They are primarily designed to teach university students about underlying GIS theory and also introduce students to the ArcView software and some GIS spatial analysis techniques. While not specifically designed to teach traditional geography content, they focus on Atlanta data that comes with ArcView 2 and could be adapted for use in a senior high school course.

Lessons from other ArcView module development efforts

ArcView-based module development efforts range from funded projects at university research centers such as NCGIA to local efforts by teachers to create materials that other teachers in the local area can use. It is difficult to identify all ArcView module development projects, especially those being developed by teachers for local use, but among higher profile projects, there appear to be only a few at this point that are funded and progressing towards a finished product. Two of these efforts are overviewed below. One is being developed by the private consultants Berkeley Geo-Research Group and the other by a partnership between the Fulton County (Atlanta) schools and the K-12 curriculum development staff at ESRI. A module that has been completed by an Oregon teacher with some input from a local resource agency is also highlighted. These module efforts are featured here to provide a flavor of what is possible in GIS module development.

GEODESY
Berkeley Geo-Research Group with co-funding from NASA is producing a module, or rather a complete spatial learning environment, titled GEODESY. This is a program which provides a GIS environment for teachers and students to study Earth systems. It uses ESRI's ArcView 2.1 software as its GIS engine, and enhances its capabilities with a series of external programs to do image processing and environmental decision-making. It is based on the use of local data to enable the user to explore the physical and human systems in his/her own community, and then to study the spatial relationships between them.   The GEODESY Knowledgebase provides on-screen documentation about the basic geographic systems (atmosphere, biosphere, lithosphere, hydrosphere, movement and settlement, cultural mosaic, economic activities, and political divisions) to assist the user in understanding the dynamics of these systems. There is a strong link to the National Geography Standards. (Geography Education Standards Project, 1994) The learning objective is to envelop teaching of the Earth into a geographic perspective where students cannot embark on any study of the environment without the analysis of spatial geographic relationships as a prerequisite for land use decision-making.

GEODESY is being developed by a team of specialists including a computer programmer and geographer, but teachers are heavily involved in the testing and revision stage of the project. Thus it is near the middle of the spectrum but on the specialist side of the Teacher/Specialist Involvement dimension (Figure 2). Students work with GEODESY in a series of phases that progress from a

highly controlled environment which introduces the key concepts of the physical and human systems through phases that give students increasing control over spatial analysis tools. Since GEODESY is software built on top of ArcView, it is close to the "Adjunct Use" end of the Mode of GIS Use dimension (Figure 3) in which the actual use of the native ArcView interface is highly limited.

The project, at the time of writing, was just nearing the end of an initial development stage of about a year and a half. A second stage which will last 1 to 1.5 years includes a set of 4 month testing, revision, and further development cycles. Personnel for the project had to help complete four main tasks: project management, data coordination/processing, curriculum research/design, and software programming. In the first year, all told, the man-hours numbered around 3500. The development platform is a Pentium 90 processor with 1.2 GB disk storage and 24 MB RAM with Windows 95 and C++ programming software. The end use platform is intended to have the capabilities recommended by ESRI for ArcView 2.

ArcVoyager
The county schools office in Fulton County, Georgia is making a major investment in ArcView for schools in their district. They wanted to create a module which would include both local and world data and that could be used in a 9th grade world geography class, but could also be understood by students in junior high. As they investigated module development, they realized that developing this module would be an undertaking that would require a strong background in Avenue programming and GIS data organization. The county schools turned to ESRI to help them make this custom module. The ESRI team chose to develop a generic module, ArcVoyager, which could be tailored to Fulton County's needs.

ArcVoyager is ArcView 2.1 heavily modified with Avenue code to create an interface with which teachers and students can be productive and exploratory in various degrees, responding to varying backgrounds.[5] A "staged" or "tiered" approach allows people to come in at Tier One without having to know anything at all except for the concept of help files and hyperlinking. At Tier Two, they can learn these ArcView operations: theme add/subtract (highly customized, not the standard open-ended method), theme on/off, theme reorder, zoom, identify, and print. At Tier Three, they can learn many more of the traditional ArcView operations, though some are still customized for ease of use. At Tier Four, they have nearly generic ArcView, and add the critical element of determining themselves what data is needed. ArcVoyager data and activities are initially customized for high school students in Atlanta, but the generic version will be made widely available and could include custom data for other states. ArcVoyager is being designed to be adaptable to any of the learning objectives outlined earlier. It could be used by a teacher to teach ArcView, to learn about GIS, to explore the geography of Georgia, or to practice spatial analysis on data from the Atlanta area.

The Teacher/Specialist Involvement dimension (Figure 22) for ArcVoyager is similar to that of GEODESY in which most of the work is carried out by specialists, but teacher feedback is incorporated into the design. With its Tiers, ArcVoyager employs various Modes of GIS Use (Figure 3), ranging from Controlled to Direct, but not Adjunct since ArcVoyager always presents a version of the ArcView interface rather than hiding it as GEODESY does.

---

[5]Althought ArcVoyager is being developed with ArcView 2.1, the relatively long timeline for the project has the ESRI developers planning to reengineer the module for ArcView 3.0 which will come out before the module is finished.

The development time for this module has been somewhat open-ended due to the need within the county schools to get the computer infrastructure in place and ensure teacher preparation. This took some pressure off the developers, but also created more opportunity for design changes which has slowed development. This project has required some advanced Avenue programming which has been carried out by an ESRI staff member. ESRI and school district curriculum development specialists have also contributed heavily to the creation of ArcVoyager. Up to this point, well over 1000 man-hours have been devoted to the project. The development has taken place primarily on Windows-based platforms from fast Pentiums to 486DX33's, although some initial work was done on a Sun Workstation. ArcVoyager is intended to be used on Pentium 75s with at least 16 MB RAM and on PowerMacs running at 100MHz also with 16 MB RAM. Fitzpatrick (personal communication) points out that in addition to the imprecise development specifications, a significant obstacle has been the widespread lack of comfort with geography as a discipline, computers as a tool, data as a raw material, and instruction through divergent exploration as a pedagogical style within the school district. This led to the need for extreme variation in design, yielding an open-ended system that was effective for many levels but "bulletproofed" for those not geared to high-end usage.

Columbia River Module

Mike Brown, a teacher at Seaside High School in Oregon, has been using ArcView with his students for the past few years to study the Columbia River and estuary area. With some data and help from a local resource management agency, CREST, he has put together a Columbia River Module which has students examine a land use issue on the estuary.[6] It involves investigating zoning issues including habitat and land use to determine an appropriate location for a new factory. This module is based on ArcView 1 since that is what Brown uses in class (hardware limitations have discouraged a quick migration to ArcView 2). The module uses ArcView to produce specialized thematic layers and hardcopy maps which help the students decide where to put the factory. ArcView 1 is just one of several technologies, software packages, and hands on activities employed by the students as they study the estuary. They also try to integrate field work (e.g., water monitoring), aerial photos, satellite imagery, GPS, and even some virtual reality modeling with their use of GIS. The primarily audience for this module is teachers (and their students) in the local area who can be trained by Brown. The learning objective is for students to use the power of the computer to help them organize information about local resources in a visual way. It is mainly content oriented (estuary studies) though also highlights spatial analysis techniques. The object is not necessarily to learn ArcView or GIS. Since Brown's students work directly with estuary researchers, students can also observe and practice research methodology, including the use of GIS in research.

This module's Teacher/Specialist Involvement dimension differs from the others explored in this report. It is primarily teacher developed with a limited amount of outside help from a local GIS-using resource agency. The Mode of GIS Use is Direct with no modification of the interface. Instead of Avenue scripts controlling the use of the module, the module includes a series of regional datasets and written materials prepared to help guide the students in their use of ArcView 1 as they work on the factory siting problem.

---

[6]The Columbia River curriculum including data can be ordered for $29 from CREST, 750 Commercial St., Room 214, Astoria, OR 97103 or from Mike Brown, Coastal Studies and Technology Center, Seaside High School, 1901 N. Holladay Dr., Seaside, OR 97138.

This module was developed over a period of two years. The development platform was a 486 33MHz IBM clone with 8MB RAM and a 250MB hard drive. Students will use new computers (Pentium and PowerMac) that have been purchased recently to complete the module.

Conclusion

Although this has not been an exhaustive study of ArcView module development efforts, these examples provide a picture of the critical design and process issues involved in GIS-based module development. The learning objective in modules often includes more than one of the four areas-- traditional subject area content, spatial analysis, GIS theory, software use--but the emphasis appears to be more towards learning content or spatial analysis rather than software operation or GIS concepts. One clear pattern that we have observed is that there is a gulf between those modules developed by specialists (computer programmers, academic geographers, graduate students, and industry representatives) and those by teachers. Teachers, for the most part, do not have the time or training to make significant use of the Avenue scripting language for module development, and are thus unable to take advantage of Avenue's ability to hide GIS complexity from the user, or to create simplified user interfaces. The specialist designed modules tend to be major projects that involve many man-hours and moderate computing resources, and thus require a large investment. ArcView 2 is favored in these major projects, due to the control of interface and operation provided by Avenue scripts. The scripting ability also provides the opportunity to explore non-traditional, innovative approaches to learning such as the tiered approach in ArcVoyager and GEODESY, which provide students with increasing access to spatial analysis tools for knowledge construction and problem solving. It is interesting that both of these modules and the series of modules developed by NCGIA all target multiple Modes of GIS Use. On the other hand the module developed primarily by a teacher focuses on Direct Use of ArcView. This may be another indication that there is a gap in the type of modules being created--broad appeal versus local interest, highly controlled versus hardcopy guided direct use of ArcView, heavy financial investment versus investment of precious teacher time rather than money.

Most of the process issues reflect the high level of commitment in human and computing resources needed for the specialist designed modules. It will be interesting to see if the relatively empty territory between small scale teacher developed modules created for limited audiences (often just for their own use) and the large module development projects begins to be populated by straight-forward, focused modules developed by teams of teachers and specialists which seek to accomplish specific learning objectives with a specific Mode of GIS Use in mind. The lack of these types of modules may be a reflection of the current status of GIS software in the schools. Significant use of these software tools in the classroom is still limited primarily to early adopters. The ArcView modules featured here should increase exposure to GIS among teachers and their students, but wide adoption may not be seen until the purpose and methods of spatial analysis are better understood by educators, until GIS software requirements become even more closely aligned with the realities of school computing, until the components of GIS analysis are packaged in special software for the schools (ArcVoyager appears to be a step in that direction), and until ease of use and access to local and global data are significantly improved. In the meantime, teachers may still find these modules based on GIS-software an exciting addition to their set to teaching tools. We hope that the framework of critical issues presented in this report will aid those developing GIS-based modules which will bring the power of GIS to the students who, as adults, will be using spatial analysis to chart paths in sustainable resource development, environmental remediation, conflict resolution, and strategic planning in the twenty-first century.

Acknowledgment

References

Carstensen, Jr., L.W., C.A. Shaffer, R.W.Morrill, and E.A. Fox. 1993. GEOSim: A GIS-Based Simulation Laboratory for Introductory Geography. *Journal of Geography*. 92(5):217-222.

Dodson, R. 1991. *NCGIA GIS Laboratory Exercises, Volume 1.* Technical Report 91-12, Santa Barbara, California: National Center for Geographic Information and Analysis.

Environmental Systems Research Institute. 1994. ArcView Helps Elementary Students Understand World Problems, Opportunities. *ArcNEWS.* 16(4):26.

Environmental Systems Research Institute. 1995a. Seaside High School Integrates ArcView into Science Curriculum. *ArcNEWS.* 17(3):23.

Environmental Systems Research Institute. 1995b. *Explore Your World: GIS in K-12 Education.* 17 minute video available from ESRI's K-12 and Libraries Program at 380 New York Street, Redlands, CA, 92373.

Fazio, R.P. and K. Keranen. 1995. Mapping: A course with GIS. *The Science Teacher*. 62(3):16-19.

Geography Education Standards Project. 1994. *Geography for Life: National geography Standards 1994.* Washington, D.C.: National Geographic Society.

Goodchild, M.F. and K.K. Kemp (1990) *NCGIA Core Curriculum in GIS*. National Center for Geographic Information and Analysis, University of California, Santa Barbara, CA.

Palladino, S.D. 1994. *A Role for Geographic Information Systems in the Secondary Schools: An Assessment of the Current Status and Future Possibilities*. Unpublished Masters thesis available at http://www.ncgia.ucsb.edu/sb/bios.html#steve. March 14, 1996.

Palladino, S.D. 1993a. *African Data Viewer.* Technical Report 93-11, Santa Barbara, California: National Center for Geographic Information and Analysis.

Palladino, S.D. 1993b. *GIS in the Schools: Workshop Resource Packet.* Technical Report 93-2, Santa Barbara, California: National Center for Geographic Information and Analysis.

Ramirez, M. 1995. Closing the Gap: GIS in the High School Classroom. *Geo Info Systems*. 5(4):52-55.

Slater, Francis. 1982. *Learning Through Geography - an Introduction to Activity Planning.* Heinemann Educational Books.

Taylor, J., J. Fletcher, K.K. Kemp. 1996. *Introductory GIS Laboratory Exercises.* Technical Report 96-xx, Santa Barbara, California: National Center for Geographic Information and Analysis.