MapStats for Kids: Making geographic and statistical facts available to children

Sven Fuhrmann¹), Alan MacEachren¹), Marshall DeBerry²), John Bosley³), Rachael LaPorte Taylor⁴), Mark Gahegan¹) & Roger Downs¹)

1) Department of Geography, The Pennsylvania State University, 302 Walker Building, University Park, PA 16802, Phone: 1-814-865-3433, Email: {fuhrmann, maceachren, mng1, rd7}@psu.edu


3) Office of Survey Methods Research, Bureau of Labor Statistics, 2 Massachusetts Avenue, Washington DC 20212, Phone: 1-202-691-7514, Email: bosley.john@bls.gov

4) U.S. Census Bureau, 4700 Silver Hill Road, Washington, DC 20233, Phone: 1-301-763-5720, Email: Rachael.LaPorte.Taylor@census.gov

Acknowledgements

The work reported here was supported by a grant from the National Science Foundation (#EIA9983451) and by funding from the FedStats Taskforce. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the funding agencies. The views of the respective government authors expressed herein are their own and not necessarily those of their respective U.S. government agencies. We wish to also thank in alphabetical order Tanuka Bhowmick, Stephen Crawford, Mark Harrower, David Howard, and Bonan Li for their inputs to and/or advice on various stages of the work reported here.
Short Bio:

Sven Fuhrmann works as Research Faculty at the Department of Geography, The Pennsylvania State University. Alan MacEachren, Mark Gahegan and Roger Downs are Professors of Geography at The Pennsylvania State University. Marshall DeBerry is the current Program Manager of the FedStats web site. John Bosley is a Research Psychologist at the Bureau of Labor Statistics with an interest in data dissemination and in software usability. Rachael LaPorte Taylor, a Information Technology Specialist at the US Census Bureau, oversees application development and content management for FedStats.
MapStats for Kids: Making geographic and statistical facts available to children

Abstract: Statistical and geographical literacy is essential for our daily lives. A new web portal for middle school students, published on the federal government statistics website, supports geographic and statistical education by providing age-appropriate online learning activities that teach how to use statistical summaries and their graphic representations. The content of the learning activities is closely related to the National Geography Standards and the Principles and Standards for School Mathematics. On average, the web portal receives 300 visitors per day.

Keywords: Geographic and statistical education, Online-learning activities, Web-portal, Geovisualization, Usability.
Introduction

Maps, statistics, and their mutual relationship play important, often ubiquitous roles in our everyday lives. When we search for a new home, we utilize maps to look up information about a neighborhood and also retrieve statistics to find out about typical prices and local costs of living. Planting flowers at our new house might require identifying the correct climate zone we are in and acquiring information about average growing season characteristics. In many cases, however, looking up geographically relevant information can be an elaborate and challenging task. Over the past several years, government web-based services, e.g. such as FedStats (www.fedstats.gov) or the National Atlas (www.nationalatlas.gov), have provided increasingly comprehensive repositories through which citizens can look up statistical and geospatial information on the Internet.

Although a wide range of spatial and non-spatial data is freely provided over the Internet, potential users are often faced with obstacles. Many citizens are connected or have access to the “information superhighway”, but some users might face accessibility and usability challenges and consequently frustration utilizing the interfaces to acquire the desired information. Frustration may lead to abandoning use of the technology and this in turn narrows electronic data access only to a few, especially if technical problems are coupled with limited technological and domain literacy, e.g. statistical and map illiteracy.

Large segments of the population are not sufficiently geographically, cartographically or statistically literate; they do not fully understand the meaning of statistical summaries and their graphic representations. Many organizations such as the International Association for Statistical
Education (IASE) and American Statistical Association (ASA) are tackling the challenge of increasing statistical and visual illiteracy in our adult population. Here we will focus on developing and supporting the achievement of statistical and graphic/cartographic literacy by middle school students through the design of a web portal that includes online learning activities based on federal statistics. *MapStats for Kids* is a research activity within the recently completed Quality Graphics for Federal Statistical Summaries project (which was supported through the National Science Foundation (NSF) Digital Government Program). The overall aim of the Quality Graphics project was concerned with designing better graphic representations for statistical data. *MapStats for Kids* focuses on graphic and cartographic representations of statistics for use by middle school-age children. It was undertaken in cooperation with the FedStats data dissemination program. FedStats is a cross-agency Internet portal designed to help visitors find statistical facts for making personal or business decisions, conduct research on a myriad of topics, and be better informed to participate in civic affairs and public policy debates.

**Children’s access to the Internet**

A recent report from the U.S. Department of Education (DeBell and Chapman 2003) states that about 90 percent of children and adolescents between the ages of 5-17 use computers on a regular base, and about 59 percent of these users also have access to the Internet. The 2001 survey indicates that computer usage starts at an early age; 75 percent of 5-year-olds use computers, while 25 percent of 5-year-olds have also access to the Internet. With increasing age the number of children who have access to the Internet rises. Fifty percent of children age 9, and
75 percent of children ages 15-17 have access and use the Internet for communication, homework and gaming (DeBell and Chapman 2003).

DeBell and Chapman (2003) found that most children are likely to access the Internet from their homes but that children from lower income families rely on Internet access in schools and libraries. In 2003 the average student-computer ratio at public schools was about 5:1, providing disadvantaged school students regular (if somewhat restricted) access to the Internet in comparison with students whose families have computers and Internet connections at home. To address the problem of income-related disparities in home Internet access, many schools provide Internet access after school hours to support school-related Internet activities such as homework (Parsad, Jones, and Greene 2005). Levin and Arafeh (2002) report that access to the Internet is essential for today’s students, because for many the Internet has become a virtual textbook and a reference library, a study short cut and often a “guidance counselor” for school, career and other life decisions.

In 2002 almost all public schools had access to the Internet using broadband connections (Parsad, Jones, and Greene 2005). Unfortunately this number does not indicate how and how often computers and the Internet are used by students in school-related activities. Earlier reports state that teachers in schools with high poverty and/or high minority enrollments were generally less likely to use computers or the Internet for instruction than teachers in low poverty and/or low minority enrollment schools. The explanations for this gap were (1) limited access to the Internet in classrooms and (2) limited support for teacher training (National Center for Education Statistics 2002). Parsad et al. (2005) describe how schools have tackled the issues of teacher
education and access to the Internet in classrooms. About 80 percent of public schools with Internet access offered professional development courses on Internet-curriculum integration to teachers and about 93 percent of public school classrooms have Internet access. However, despite reports of nearly complete school-level access to the Internet and improved teacher training, little data is available on the actual use and usefulness of the technology in classrooms (National Center for Education Statistics 2005).

GIS in Schools

One benefit of increases in computers with Internet access in schools is that it has become possible to introduce Geographic Information Systems (GIS) into public schools. First initiatives started in the early nineteen nineties and have caught on as computers have become more commonplace in classroom use (Audet and Ludwig 2000; Green 2001). The National Geography Standards for school education (Geography for Life), written in 1994, recognized GIS as important technology for the geographic domain, and illustrated the possible uses of GIS in meeting the standards. Because the technology was still novel for school use at the time, the National Geography Standards did not require the use of GIS in geographic education (Geography Education Standards Project 1994). Since publication of the geography standards, GIS integration into school curricula has been discussed, but not adopted explicitly as part of the National Geography Standards (Palladino and Van Zuyle 1996; Green 2001).

ESRI and other major GIS companies have been very active in introducing GIS products into K-12 schools. The Association of American Geographers, the U.S. Geological Survey, the National
Council for Geographic Education and other organizations have supported many initiatives to support the use of GIS in classroom activities and beyond. Their activities have produced general publications for teachers and parents about using GIS in schools (Audet and Ludwig 2000; English and Feaster 2003), and have resulted in a GIS guide for educators, with lesson plans that are mostly based on the National Geography Standards (Malone, Palmer, and Voigt 2002). In a recent press statement (ESRI 2005), ESRI announced an electronic magazine for GIS and geographic learning in primary and secondary education. Many examples of secondary school students using GIS in classroom settings and in the field have been reported. Examples range from applying GIS in (1) hazardous material accidents (Paul and Hamilton 2000), (2) land-use mapping (Walker 2001), (3) watershed assessment (USGS 2005) and (4) cultural geography (Thompson, Alibrandi, and Hagevik 2000). Nearly 200 lessons plans can be downloaded from the ESRI ArcLessons web site at

Despite the numerous efforts and materials provided, Kerski (2003) found that less than two percent of American high schools are using GIS for educational purposes. Baker (2005) argues that main barriers to GIS in K-12 education are complex interfaces and functionalities that were not designed for student use in schools, resulting in a time-consuming and frustrating learning experiences for teachers and students. Geospatial technologies clearly offer great potential for problem-driven learning experiences; one key to greater acceptance lies in providing age-appropriate geospatial activities and applications that feature task and domain-specific functions and interfaces.
Learning to think analytically about statistical information through use of graphs and maps

This project uses a different approach than a traditional desktop GIS to help school students learn about the potential of federally produced statistical information and its spatial and statistical analysis. Our goal is to provide students with the opportunity to learn about and understand how to use the vast sources of statistical information in a wide range of everyday activities. Today, the Internet and geospatial information technologies allow us to build age and task-appropriate web platforms and applications that can have a large and positive impact on student’s essential statistical and geospatial skill-building processes.

MapStats for Kids provides a web portal and a set of online learning activities for middle school students (and their parents and teachers) that embrace and integrate statistical information, spatial data, spatial and statistical analysis, and visual representations. The online learning activities are based on GIS tasks, but provide age and task-specific content, interfaces and functionalities that stimulate the student’s interest to explore existing statistical and geospatial datasets.

The foundation for our research was the NSF Digital Government Project, “Quality Graphics for Federal Statistical Summaries” (dgQG). Academic researchers and federal agency personnel collaborating on this project identified a series of public information access and dissemination challenges to which project research activities were directed. One of these challenges was to make federal web sites more accessible to children and more useful for promoting learning.
related to the wide range of activities undertaken by the federal government. It was obvious that the cognitive demands of operating web information portals designed for adults were too high for children and that the methods for enabling access to statistical summaries were too abstract. In general the Internet portals offered children limited access to assistance, navigation support, data explanations, help in understanding graphical representations, or information about what the data could be used for. Nielsen (2002) argues that: “Despite this growth in users and services, very little is known about how children actually use websites or how to design sites that will be easy for them to use”. Recognizing these accessibility and usability problems, the MapStats for Kids project goals were not to make the FedStats (or other federal websites) accessible to school students generally, but to design a web portal that

- provides online learning activities for middle school students within the FedStats program,
- interests students in statistical information (and the maps and graphics used to communicate or work with that information) and,
- helps students learn how and where to use such tools.

The online learning activities were focused on geospatially-referenced, federal statistical summaries.

**The conceptual approach**

A large body of research demonstrates that it is impractical to develop a “one-size-fits-all-ages” web portal or set of online learning tools for school students (Sullivan et al. 2000; Large, Beheshti, and Rahman 2002). Middle schools generally include grades six to eight and thus the
MapStats for Kids web portal needed to be developed for children approximately between the ages of twelve and fourteen. Nielsen (2005) argues that websites for young teenagers should be simple but not childish and should supply interactive features. The attention span of children is usually relatively short and they will leave a website that is difficult to figure out. Children are excessively challenged with websites that are designed for adults. In tests, websites designed for adult use achieved only a 55 percent success rate for young teenage users. Nielsen (2005) concludes that the poor website performance might be caused by a) insufficient reading skills, b) less sophisticated research strategies, and c) lower patience levels (in comparison to adults).

We addressed these three issues by developing online learning activities and web content that match the geospatial and statistical knowledge, skills, interests and experiences of middle school students and the current national education curricula, especially the “Principles and Standards for School Mathematics” (National Council of Teachers of Mathematics 2000) and the “National Geography Standards” (Geography Education Standards Project 1994).

Web-based, interactive maps and graphical-based learning activities offer possibilities for visualizing federal statistics and at the same time can support an integrated approach to educational standards across subject areas. Our approach in the MapStats for Kids project was built on two fundamental ideas: (a) fostering an exploratory, flexible, problem-solving approach to the use of statistical data, and (b) supporting the development of sets of knowledge and cognitive skills that underpin the use of statistical data. For middle school students, statistical data is most useful if it can be readily converted into information that students can apply to answering a question or solving a problem. Useful and usable visual displays and interactive
visualizations of quantitative information are a key to age-appropriate data exploration, problem solving, and the development of knowledge and cognitive skills (Tufte 1983).

A core objective for the web portal was to attract students by providing interesting, accessible, challenging, informative and useful content. Crucial to this idea was (a) an appreciation of the cognitive skills that underpin successful performance (Liben 1999), (b) a recognition that the skills develop over time as children mature (DeLoache 1989), and (c) an awareness that there are individual differences in performance of the same tasks for children at the same age range (Liben 2000). While children need to develop many skills (e.g. logico-mathematical, linguistic, music, spatial, bodily-kinesthetic, interpersonal and intrapersonal skills (Gardner 1998)), the goal of the MapStats for Kids learning activities was to support developing three skills that are central to statistical and geospatial data analysis: (a) logico-mathematical skills, (b) representational skills, and (c) spatial skills.

Technical concept of the web portal

In addition to the cognitive aspects of activity development for middle school students, technical requirements are important. An important consideration in the development of a web portal and online learning activities is to ensure that the applications are portable to a variety of web environments (e.g. Mac OS as well as Windows, Firefox as well as Internet Explorer), and that they adhere to the requirements of the Section 508 access and usability requirements relating to federal web sites (http://www.section508.gov).
The information representation components of the web portal (containing mainly HTML content) were created using Adobe GoLive. The online learning activities and some graphic components of the web portal were designed using Macromedia’s Flash software. Macromedia Flash is a multimedia authoring environment that allows the distribution of program code, vector and bitmap graphics, and streaming audio and video for learning applications. Newer Flash versions also allow the design of bi-directional streaming audio and video applications that not only receive video and audio signals, but also enable users to broadcast and engage in video and audio communication (http://www.macromedia.com). Flash allows designers to quickly develop dynamic applications that are visually appealing, highly interactive, web compatible, and highly usable (if correctly designed). In these applications, Flash graphics are often integrated as vector-based graphics (as opposed to raster images). Vector graphics usually do not occupy as much file space and consist of descriptions that define individual properties of a graphic such as geometries, colors, labels, etc. Because of smaller file sizes, the use of vector graphics results in quicker download times and meets the requirements of young and impatient web users. Furthermore Flash applications run well on older computers (a concern for classroom and home use, because many older computers are handed down to children from parents or others), and the software required to view Flash content is bundled with most web browsers or is otherwise available for free from the Macromedia website (http://www.macromedia.com/downloads).

There are a few barriers to accessing Flash content online. One of the most important barriers is that (due to the binary (non-text) encoding of Flash applications), most search engines are unable to search the content of Flash applications, resulting in lower visibility on the Web. Macromedia has started to address accessibility concerns; features for disabled users were integrated into the most recent version.
Perhaps the most important factor for choosing Flash as a development environment is that Flash applications can be data-driven, allowing designers to build applications that can accept data from any one of several multiple federal agency partners. Our online learning activities import federal data that are formatted as Extensible Markup Language (XML). XML has become an open standard for the interchange of documents over the World Wide Web. While the Hypertext Markup Language (HTML) defines how elements are displayed in the web browser, XML defines what those elements contain. Applying XML allows us to use a variety of datasets and exchange the datasets quickly and easily if desired. Over the last few years, therefore, Flash has become the de-facto standard for dynamic web content and its ability to import data makes it well suited for activities focused on statistical data depiction.

The MapStats for Kids web portal

Our work resulted in the MapStats for Kids web portal that is now published on the FedStats Website (http://www.fedstats.gov/kids/mapstats/index.html). The overall web portal was designed with low performance computers and networks in mind, since many classrooms feature only older computers and many families still connect to the Internet through 56k modems. The learning activities require Flash Player 7 and the minimal system configuration of a 266 MHz processor, 64 MB RAM, and a monitor that supports the display of 256 colors at 800 x 600 pixel resolution. The minimal system configuration was tested on various operating systems before publishing it on the FedStats website.
The overall design of the web portal was also guided by three human factors that influence website acceptance: reading skills, research strategies, and patience level. As part of our efforts to ensure the age and skill appropriateness of the texts provided and the compliance with national standards, the website content was proofread by a teacher. Search strategies on the web portal were kept to a minimum by designing the web portal and the online learning activities for smaller monitor resolutions that require no (or only minor) scrolling, while also providing modest, clean interface designs with “cool” looking graphics. Small application and graphic file sizes support a fast download and good run-time performance, even on older computers.

The homepage of the web portal allows quick and easy access to five online learning activities and provides links to additional resources such as map and statistics concept explanations, teacher and parent information, and a link to the main FedStats web portal (Fig. 1). “Globie” and “Stixie” are characters designed to guide the students through the website and through animation, to stimulate users to learn about statistics and mapping.

“Stixie” and “Globie” explain all of the statistical and mapping concepts that are applied in the five online learning activities. Students can learn about map concepts such as projections, topological relationships and color schemes or statistical concepts such as frequency, median and pie charts. Quizzes allow students to find out if they really do understand the explanations. The MapStats of Kids web portal also provides information resources for parents and teachers. These resources give an overview about the technical requirements, learning objectives, educational benefits, and national educational standards that are associated with each of the learning
activities. The resources also provide links to the full online versions of the “Principles and Standards for School Mathematics” and the “National Geography Standards”.

Graphics and application descriptions provide initial access to the online learning activities. The explanations include information about general tasks and goals of the activities and indicate also the level of difficulty. Color indicators help in navigating the website by showing which of the activities has been currently selected. Clicking on a screenshot of the learning activity will start the *Flash* application. The essential learning goals are explained to the students before the online learning activity starts, so they know what content the activity will focus on.

Fourteen middle school students and their parents helped us in a thinking aloud study to test the web portal and the online learning tools for usability. The results were used to discover major flaws and to suggest redesigns for the portal and learning activities where needed\(^1\). The five learning activities are called (1) Paint the Map, (2) Data to Graphics, (3) The Network Challenge, (4) Market Manager, and (5) Farmland and will be further described in the following sections.

**Paint the Map**

The first online learning activity in the available set is a map-puzzle in which students build (or paint) a map to represent state-level statistics. In this activity, school children need to (1) identify the US states (at the beginner level the map includes US state labels; at the advanced level the map does not provide labels and thus, requires the learner to know which state is which), (2) categorize states by interpreting data represented numerically or in bar charts, and (3) “paint” the

\(^1\) A formal analysis of the student/parent pairs will be published as a complementary paper.
identified state with the correct color, representing a value of some statistical factor that most accurately characterizes the state (MacEachren, Harrower et al. 2002). This activity offers educators the potential to introduce the statistical concepts of mean and median and allows the comparison of US states on a variety of factors, e.g. household income, energy consumption or population change (Fig. 2). The resulting maps depict regions of the U.S. that fall above or below (or at) the specified measure of central tendency.

Data-to-Graphics

At the core of understanding the mapping of statistics is the ability to move between graphical and tabular data representations (MacEachren, Downs et al. 2002). The primary goal of the Data-to-Graphics application is to foster an understanding of typical summary statistics through tabular and graphical representations of data by exploring the connections among a spreadsheet, a map, and a graph. Students learn about ranking, value categories, central tendencies, and value representation through bar graphs (Fig. 3). Students need to find the value for a state in a table (energy consumption, population data, etc.), then find the bar that represents the state in a bar graph and adjust the top of the bar so that the height is the same as the state value in the table. Finally students need to color a choropleth map by identifying the correct value of the state in the legend and dragging the correct color from the legend into the map. Students can look up values for the choropleth map either in the table or the bar graph. This activity helps students to understand that statistical data can be represented in many different ways and that each representation has different properties and application areas.
The Network Challenge

Decision-making is irrevocably part of our everyday lives. We make decisions all the time and while we make decisions, we need to think about how these decisions might affect future decisions. The Network Challenge requires one to not only make the "next best move", but to think about how one choice relates to the next decision. In the third application students have to keep the final goal in mind. The activity (Fig. 4) uses a network travel map as the base for addressing a range of learning objectives associated with use of summary statistics in sequential decision-making. The Network Challenge activity focuses on the concept of networks. Specifically it addresses the understanding of topological relationships and problem solving strategies to support spatial decision-making related to traversing a network. In this learning activity, a user (student) uses data presented in a map, table, graph, or look-up card to plan efficient and effective routes (campaign stops, band tours, vacation trips), starting from a randomly generated state capital (MacEachren, Downs et al. 2002).

Market Manager

The fourth learning activity is the Market Manager. It focuses on the concept of regions, specifically on building comparable sales regions that balance population and demographic characteristics of the population (Fig. 5). It has two levels. Level 1 contains the ice cream distribution challenge as a predefined activity, while Level 2 allows educators to customize the application and select different data sets (within predetermined constraints). The application operates at three different geographic frames of reference: national, state, and greater metro area.
At each scale, the goal is to classify the units (states, counties, or ZIP-codes) into four contiguous regions (market territories) with equal aggregate values (e.g. populations of children aged 5-17 in each territory).

**Farmland**

Many federal datasets have a temporal component, and time-series maps (e.g., temporal animations) are a way of showing changes in these datasets over time. *Farmland* shows these changes through temporal animations that allow the user to view changes over the entire temporal range, and to explore the data dynamically by jumping between times of interest. Students learn about how temporal maps are an effective way of displaying these changes, the way data are classified (natural breaks, equal intervals, etc), and how color can represent different classes on a map. The graphical interface uses the CD player button metaphor, which supports playing the animation, stepping through the animation in forward or reverse directions, and pausing or resetting the display. A slider on the timeline allows users to move the animation through a desired range at a desired rate. Three different types of farm data by state for the U.S. are included: number of farms (1910-1999), average farm size (1950-1999), and acres in farms (1950-1999). Several monochromatic color schemes can be selected to view the datasets (Fig. 6).

**Conclusions**

Before the *MapStats for Kids* web portal and the online learning activities were published on the FedStats website, team members from the GeoVISTA Center and the Bureau of Labor Statistics
(BLS) conducted a variety of usability assessments such as an online-questionnaire, focus group test, and expert review with media specialists and teachers. The information was used in an iterative revision process. The revisions were complemented by participant observations. Middle school students (accompanied by a legal guardian) were introduced to the learning activities and the web portal and instructed to use the web applications. While working with the activities, children were asked to verbalize their thoughts and problem solving strategies. After completing the tasks the students were interviewed through a structured interview designed to explore their understanding of the application and their understanding of the domain knowledge and related concepts that the application focused on. These usability assessments were essential to the revision process of the web portal and the online learning application design.

Designing web content for school children is not an easy task, especially when the design has to be compatible with an overall agency website design that is developed for adults. Our overall goal for MapStats for Kids content was to produce graphically attractive, usable, and useful web pages and online learning activities that (1) attract users’ (middle school students) attention and interest, thus encouraging them to explore the website, (2) include stimuli that are viewed as fun (but serious), easy and interesting to use, and (3) provide a positive learning experience. With these three points in mind we focused not only on students, but also on parents and teachers who might use the website for class preparation or home school activities. With the MapStats for Kids addition to the FedStats site, these goals are being addressed, and this project has taken the initial steps to better illuminate the issues relating to statistical literacy. MapStats for Kids receives an average of 300 visitors per day. Please feel free to access the web portal at http://www.fedstats.gov/kids/mapstats/index.html to experience first-hand the learning activities
it affords. In future projects and collaborations we will continue enhancing the usefulness and usability of web portals for children.
Literature


Figure Captions

Figure 1: The MapStats for Kids web portal
Figure 2: Paint the Map learning activity
Figure 3: Screenshot of the Data to Graphics application
Figure 4: The Network Challenge
Figure 5: Creating regions with the Market Manager
Figure 6: Animated data in the Farmland activity
Hey Kids!

We are Sticia and Ghibia. We teach you concepts about maps and statistics through cool games. Do you think you can answer these questions? If not, the games will help you. Let the fun begin...

Tell me more: What is this about? What will I learn? Tell me about it. Give me more information.

FedStats MAPSTATS for Kids

This site requires the use of Macromedia Flash Player plug-in. If you do not have Flash or are unsure of its installation, please follow the link below.

Macromedia Flash Player
Number of Farms by State 1910-1999

Number of Farms

- Less than 1,000
- 1,000 to 2,000
- 2,000 to 10,000
- Greater than 10,000

1910
1940
1990
2000

Use the slider or buttons to explore the timeline.

Sources: www.fas.usda.gov