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Integrating GIS with Geographic and Environmental Education into K-12: an Interdisciplinary Curriculum Development Entitled Studying the Environment of Eighteenmile Creek

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GIS를 지리환경교육에 통합하는 교육과정 개발에 관한 연구: 뉴욕주 버팔로 지역의 Eighteenmile Creek에 관한 수업 안 개발을 사례로

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Abstract : Geography has played a role of serving as a bridge between the natural and social sciences for long time and can be an interdisciplinary framework. In this research, the effectiveness of an interdisciplinary approach centering on a geographical perspective in environmental education is presented. On this basis, a syllabus for seven 90-minute classes for the 8th grade is established under the topic of "Studying the Environment of Eighteenmile Creek." This interdisciplinary framework will be strengthened and vitalized through GIS, which plays an important role to make the geographic and environmental education more student-centered, active, and relevant to the world where we now live.
Key Words : geographic and environmental education, interdisciplinary curriculum, Geographic Information Systems (GIS), curriculum development

요약 : 지리학은 오랫동안 자연과학과 인문과학을 연결하는 역할을 수행해왔기에 학문 간의 통합적 시각으로서의 특징을 갖는다고 할 수 있다. 본 연구는 이러한 지리학의 통합학문으로서의 역할에 기초하여 환경교육에 접근하는 통합교육과정의 효과를 먼저 고찰하고자 한다. 이를 바탕으로, "에잇틴마일 크릭의 환경 연구"라는 제목으로 8학년을 위한 일곱 차례의 90분간 수업을 위한 수업 안을 구성하였다. GIS는 지리환경교육을 보다 학습자 중심의 교육으로, 보다 적극적인 학습이 이루어지게 하고, 또한 우리가 살고 있는 삶을 중심으로 하여 실생활과 밀접한 학습이 가능하도록 하는 중요한 역할을 감당할 것으로 기대되며, 이를 통해 지리학을 중심으로 하는 다학문간의 통합적 시각을 강화하고 활성화할 것이다.
주요어 : 지리환경교육, 통합교육과정, 지리정보체계, 교육과정개발

1. Introduction

A popular Native American quotation, "Tell me, and I'll forget. Show me, I may not remember. Involve me, and I'll understand." is supported by many researchers. It is especially true in environmental education, where it is crucial for learners to participate in their own community based on cognitive knowledge building about their own environment. To

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achieve successful environmental education, involving learners with real world environmental problem solving is the key and is only possible when the learner's belief system is changed through the process of learning.

Recently, as a method of involving students in environment study, Geographic Information Systems (GIS) have been favorably received as innovative and exciting tools. However, it doesn't come without a caveat. This study seeks to highlight these acclamations about the potential of GIS and awareness about its limitations and pitfalls. The primary purpose of this study is to present an example of a desirable environmental study curriculum by using GIS and geographical perspectives. For the purposes of this paper, we integrated GIS, focus on interdisciplinary subject matters, and address environmental values. Also, we framed environmental education in a multi-dimensional model following McKeown-Ice (1994) in order to implement environmental education effectively.

The paper is composed of six sections including the introduction. The next section reviews the related literatures in geographic and environmental education. The third section gives a brief description of the curriculum and its connection to current New York State Social Studies Resource Guide with Core Curriculum and National Geography Standards. The fourth section focuses on actual curriculum development process with GIS, which includes data documentation, data pre-processing, and data analysis and modeling. The discussions about this newly developed curriculum are presented in the fifth section and are divided into sequence of lessons and activities and assessments. The final section contains brief conclusions and discusses about the limitation and further work of this study.

2. Literature Review

This paper combines ideas from three topics: environmental education, geographical perspectives, and GIS. After discussing the relevant points in each topic, we outline a multi-dimensional environmental education framework with GIS and geographical perspectives necessitated by our synthesis.

1) Environmental education

Environmental education is of critical importance to the future of our students because it offers a vision of our common future (Bruntland, 1987) and promotes progress toward sustaining a healthy environment and quality of life. Environmental education has been defined in various ways. One of the current and broadly accepted definitions is "Environmental education is a process aimed at developing a world population that is aware of and concerned about the total environment and its associated problems, and which has the knowledge, attitudes, motivations, commitments, and skills to work individually and collectively toward solution of current problems and the prevention of new ones" (UNESCO, 1976). Environmental education depends on scientific knowledge, but it is also related to social, economical, cultural, and political issues to a large extent. Thus, environmental education, it might be argued, should be approached through interdisciplinary and/or multidisciplinary methods.

2) Geographic and environmental education : an interdisciplinary approach to environmental study with geographical perspectives

Geography can serve as an interdisciplinary framework, which is quintessential for effective for environmental education. However, the general public is mostly unfamiliar with the geographer's far-reaching interest, researches, and literatures relating to the environment (McKeown-Ice, 1994). This interest originated from a long tradition of geography connecting the environment to society. From ancient times, geographers have researched both natural and cultural landscapes, thus forming a disciplinary bridge between the natural and social sciences.

Pattison (1964) observed the four traditions of geography in order to respond to the both points of view about geography, the "omnium-gatherum" and the monistic view. He entitled those traditions a man-land tradition, an earth science tradition, a spatial tradition and an area studies tradition. After discussion of each, however, Pattison (1964) concluded that although these four traditions looked distinct logically they were often connected with each other in actual studies. Geographers have conducted all four of them at the same time. With regard to environmental study, especially the man-land tradition deals with the human impact on nature and nature's impact on people and an earth science tradition focuses on the environment itself. It should be noted, too, that whenever a geographer performs his or her study about environment, he or she always pursues the third and fourth traditions under the constraints from the first and/or second traditions.

The aspects of the four traditions were reemphasized by McKeown-Ice (1994). She reviewed the four major ways in which geographers study the environment: the natural environment using scientific methods and techniques; the impact of human behavior on the environment; environmental influences on human behavior; and the different cultural perceptions of the environment and how these perceptions are expressed in the surrounding landscape. She also argued that geographers examine spatial patterns of environmentally related topics at different scales-local, regional, and global- and the interconnections of the global environment and economy. She recognized that environmental education that would have no consideration for the scale factors and their interconnections might leave something to be desired. Thus, she suggests that even if a course is highly organized covering many areas of environmental education, the learners should be able to decide for themselves whether the scale factors will be used, and if so, when, where, in what way, and to what extent.

3) GIS as a tool of educational reform

Much literature has been written regarding the benefits of GIS in K-12 education as a tool to support educational reform goals (Audet, 1994; Audet and Abegg, 1996; Bednarz, 1995; Kemp and Goodchild, 1991; Palladino and Goodchild, 1993; Sui, 1995; Walsh, 1988; White and Simms, 1993). However, the lack of GIS-based lesson modules is one of the main barriers that have slowed the successful implementation of this software into the curriculum. Bednarz and Baker (2003) also pinpoint appropriately that teachers and educational practitioners will not employ GIS into their classroom unless they are fully convinced of its effectiveness in enhancing meaningful learning.

Among them, we understand the most demanding need is the holistic perception of teaching and learning associated with GIS and education. When integrating GIS into the classroom, instead of not just adding GIS like other technologies, the educational experience should drive the use of technology and not the other way around. Many anecdotal stories from teachers in the class revealed that it is possible to do computer exercises and not understand the underlying concepts or even the reasons for carrying out a particular task. Also there are many variables which influence learning such as the student's readiness and motivation, the subject matter involved, the teacher's theoretical background and the socio-economic environment around classroom. So, it's obvious that a wiser teacher decides where he or she puts the priority. "Integrating" GIS into classroom, thus, might be possible only when we fully understand those variables.

This is being increasingly viewed by educators as problematic, and there have been only a handful of carefully executed research efforts in this area. Studies have typically investigated environmental education by using GIS in terms of the degree of application. This one-dimensional gauge, however, does not allow representation of the diverse patterns of environmental study.

4) Multi-dimensional environmental education and an example of curriculum

In response to the previous literature review, we synthesized that interdisciplinary methods, centering on geography, and integrating GIS into classroom might be able to serve as a catalyst to move teachers toward an instructional style that is effective and efficient in the environmental education.

Following McKeown-Ice (1994), we framed environmental education in a multi-dimensional model in order to implement environmental education effectively. We suggest that it should be aligned with four dimensions of environmental study (natural environment,

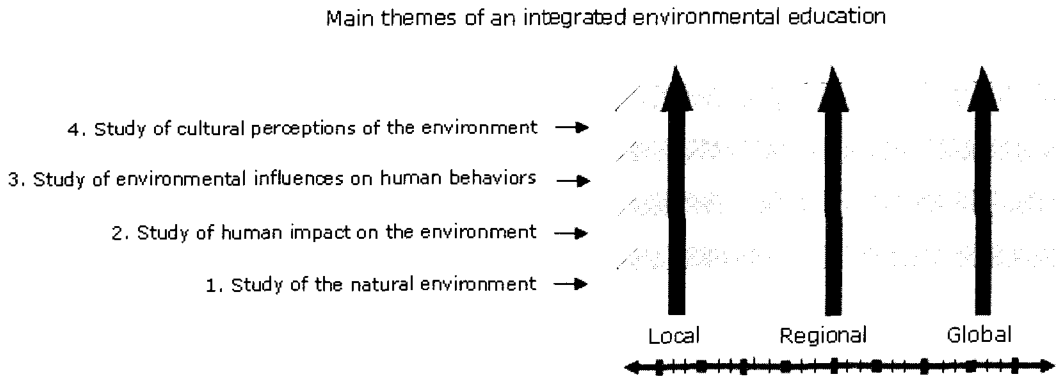

Figure 1. Multi-dimensional framework for environmental education (Figure is drawn, on the basis of McKeown-Ice (1994))

Table 1. A sample for multi-dimensional curriculum for geographic and environmental education

	Local	Regional	Global
1. Study of the natural environment	• Watershed • Water quality • Hydrologic Unit Code (HUC[1]) (to understand the basic concepts about environment)	• Degradation of Lake Erie	• Pollution of large water body (to understand the global implications of local environmental degradation)
e.g.	Eighteenmile Creek	Lake Erie	North Atlantic Ocean
2. Study of human impact on the environment	• Road-density (to understand road-density has impacts on the wild life)	• Compare with another region in New York State	• Compare with another country
e.g.	Eighteenmile Creek watershed	New York City	Asia (China)
3. Study of environmental influences on human behaviors	• Road-stream crossings • Impact of slope	• Compare with other region in the United States	• Compare with other country
e.g.	Eighteenmile Creek watershed	San Bernardino	Middle East (Egypt)
4. Study of cultural perceptions of the environment	• Population's perception of the value of resources: i.e.) road pattern or oil consumption	• Compare with other State in the United States	• Compare with other country
e.g.	Erie County	California	South America (Brazil)

human impact on the environment, environmental influence on human behaviors, and cultural perceptions of the environment) along with the scale factors (local, regional, and global). Figure 1 illustrates the conceptual framework of multi-dimensional environmental education. The following table (see Table 1) illustrates a sequence of lesson units as a sample of the multi-dimensional curriculum.

Up to now, "how can we actually materialize environmental education in the classroom?" is reflected on the basis of a multi-dimensional environmental education framework. This conceptual framework zoomed into the issues about the necessity of the interdisciplinary method, and the possibility of centering on geography as a core discipline when combining natural science and social science. Also, GIS might play an important role to make the environmental study more student-centered, active, and relevant to the world where we now live.

3. Curriculum Description

A model for geographic and environmental education was developed with emphasizing both the interdisciplinary method and geographical perspectives. Also, this model put stress on integrating GIS into geographic and environmental education as a powerful tool to improve students' higher order thinking. Following these theoretical and conceptual frameworks, this section primarily describes the actual curriculum as an example of the desirable geographic and environmental education.

For this project, ArcView[2] will be mainly used as a GIS software, which is the most popular K-12 GIS package in the U.S. Through the discussion with a teacher who has participated in this project, we decided to use ArcView because of its easiness and availability in her school district. We have met this teacher usually after school for 6 months bi-weekly, trained her to get familiar with GIS technology and conferred at great length about the interdisciplinary curriculum development using GIS prior to actual classroom implementation. Currently, the empirical data collection is in progress with her 8th grade Biology class. However, we limit this paper to the phase of curriculum development as mentioned in the previous sections.

1) Topic

The curriculum was entitled "studying the environment of Eighteenmile Creek." This topic was cautiously selected to address the following four main issues of this research:

- Fostering students' awareness of the community in which they live;
- Providing a "real-world" introduction to the tools of GIS and computer graphics design and illustration tools;
- Encouraging students' deeper involvement and understanding of diverse issues and problems of their community; and
- Promoting interdisciplinary approaches to solve "real problems"

This topic is considered to be suitable to deal with the interdisciplinary nature of environmental education which includes the concepts of geography, earth science, language art, and even mathematics of the study area.

2) Target grade

Basically, this curriculum was developed for 8th graders while we have worked together with an 8th grade Biology and Life Science teacher of a public middle school in the Buffalo suburban area. The appropriateness of curriculum for the target grade was also examined by reviewing the current New York State Social Studies Resource Guide with Core Curriculum and National Geography Standards. Using this curriculum, students will collect information from maps, remotely sensed images, reference books, and websites. The students will also manipulate data, utilize the GIS tools and study "real problems." Surely enough, this curriculum can be accommodated to other target grades by adding or removing one or more concepts, factors, and GIS tools.

3) Big idea: "Where does the water go?"

If you flush the toilet, where does that water go? If you wash your hands, where does that water flow? Wherever you are located, that water finds its way to one point, an estuary and eventually to the sea. The boundary of the area within which all water moves to the same point is called the watershed or drainage basin. John Wesley Powell put it best when he said that a watershed is:

"that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community." (US EPA, 2007)

This statement illustrates how connected and dependent we are to a watershed. Even if in fact we are living in our own watershed, the term "watershed" is not familiar to most students. Therefore, the primary learning goal of this unit is that students are able to be aware of the fact that "I'm sitting in a watershed now."

As shown in the famous motto of an environmental movement, "community to community, watershed to watershed," a healthy watershed is vital for a healthy community (Conservation Technology Information Center, 2007). Only when the students realize the relevance of the watershed to their daily lives and to their community, will they start to absorb environmental ethics and to exhibit environmentally sound behaviors. Without this self-awareness process, environmental education is alienated from real life and finally degenerates into another subject of rote memorization.

4) Contents

In this unit, a sub-basin (area of 39.28 sq. mi.) of the Eighteenmile Creek in the Buffalo River - Eighteenmile Creek Watershed, 04120103 (HUC, Hydrologic Unit Code) is selected as the study area for the students who live in this watershed. The main purpose of this unit is to research their own watershed, diagnose the watershed health status, investigate the problems, and find possible solutions to solve the problems. For these purposes, the first part of the unit is for students to locate their own watershed using the searching program through the Internet. The road- density and the road -stream crossings are designated as indices of the watershed health condition. Before beginning the real content of the curriculum, students will "play with" the GIS program to become familiar with it.

5) Connection to current New York State Social Studies Resource Guide with Core Curriculum

This unit plan is connected to Grades 7-8 Social Studies: United States and New York State History. Social studies content in grades 7 and 8 focuses on a chronologically organized study of United States and New York State history (NYSED, 1999). The course content is divided into 11 units, tracing the human experience in the United States from pre-Columbian times to the present, and tying political, geographic, economic, and social trends in United States history to parallel trends and time frames in New York State history. Among those units, "II. The United States Begins a New Century" under the "Unit Eleven: The Changing Nature of The American People From World War II To The Present" includes "D. Old and new problems must be addressed." This content outline mentions about "2. Protection of the environment".

Although "Environment and Society" as a concept or theme is accompanied by "protection of the environment" in its content outline accordingly, it is very superficial. Overall, the New York State Social Studies Resource Guide with Core Curriculum places little emphasis on the environmental aspect for the grade K-12. If we agree that environmental education should be approached from interdisciplinary methods, the NYS social studies Resource Guide with Core

Curriculum leaves much room for improvement.

6) Connection to current National Geography Standards

The Geography Education Standards Project developed the National Geography Standards using curriculum materials collected from many countries as well as materials familiar to most teachers in the United States, such as states and local curriculum frameworks and the 1984 Guidelines for Geographic Education: Elementary and Secondary Schools. Thus these standards evolved from the geography community's thinking about what constitutes appropriate and challenging contents (Geography Education Standards Project, 1994). To create a "geographically informed person," which is the main goal of the National Geography Standards, they suggest 6 essential elements and 18 standards. Among them, the fifth element, environment and society is focused on this unit plan and in accordance with 3 standards as shown in Table 2.

4. Curriculum Development

Previous section outlined a sample curriculum based on an interdisciplinary environmental education model with GIS. Under the topic, "studying the environment of Eighteenmile Creek," a series of curricula will be developed to achieve the goals of enhancing the students' environmental ethics and of involving environmental behaviors. For these purposes, integrating GIS into the curriculum is the main focus of this study. However, people have a wide-spread suspicion that GIS is too much an up-to-the-second technology for teachers and students to learn how to use it. Especially, it takes considerable time and effort for a teacher to employ GIS into an actual curriculum because he or she need to go through the procedures of collecting, pre-processing, and analyzing data, which is relatively difficult for the person who is not yet familiar with GIS. In this chapter, the actual curriculum development process with GIS will be explained in detail in order to help teachers substantially with curriculum develop-

Table 2. Essential elements and geography standards in the Geography Education Standards Project (1994) and its connection with this unit

Essential Elements	Geography Standards	Concepts and Examples
V. Environment and Society	Standard 14. How human actions modify the physical environment Standard 15. How physical systems affect human systems Standard 16. The changes that occur in the meaning, use, distribution, and importance of resources	1) Concepts: • Watershed's importance to communities • Road density as a human impact on the watershed environment • Road destruction as environment impact on human system 2) Examples: • Watershed delineation using GIS • Calculating road density • Using GIS to determine threats of road construction • GIS for watershed management

ment, which includes data documentation, pre-processing, and analysis.

1) Data documentation

In this study, mainly three kinds of data were used: road, Digital Elevation Model (DEM), and stream data. It should be noted that all these data employed in this study are available to the public and downloadable for free. The fact that it is hard to acquire inexpensive, reliable, and good quality data is one of bottlenecks that slow the growth of GIS use in the schools. Thus, in this study we will use open source data to overcome the expensive price of GIS data even though this compromises the high resolution of data.

First, the road data applied in this analysis contains the major and minor roads of Erie County. The data set was acquired from the Planning Department laboratory at the State University of New York at Buffalo, which was originally created by the New York State Department of Transportation (NYSDOT). Second, to extract the sub-basins of rivers and to achieve further analysis, the DEM was used. DEM data are produced by the National Imagery and Mapping Agency (NIMA) in 1- by 1-degree units that correspond to the east or west half of the United States Geological Survey (USGS) 1- by 2-degree topographic quadrangle map series (1:250,000-scale) for all of the United States and its territories. The 1-degree DEM data are referenced geographically with the horizontal datum of the World Geodetic Survey (WGS) system of 1972. Third, the stream data set was downloaded from the Cornell University Geospatial Information Repository (CUGIR) website for the hydrography of Erie County.

2) Data pre-processing

Launching GIS program, a user might be confounded because the map doesn't show up in spite of adding two or more data appropriately from the data source directory. One possible cause is that those data have different properties. To troubleshoot this problem, the user must manipulate the data, identify the coordinate system, or change the projection. This process is often called data preprocessing, which describes any type of processing performed on raw data to prepare it for another processing procedure. Commonly used as a preliminary data manipulation practice in a GIS analysis, data preprocessing transforms the data into a format that will be more easily and effectively processed for the purpose of the user. The main data (i.e., roads, streams, DEMs) of this research have different properties from each other because they were captured from various sources. Thus, prior to analysis, map projections and coordinate systems should be changed as a data preprocessing step. By definition, changing a map projection or projection transformation is "the mathematical conversion of a map from one projected coordinate system to another, generally used to integrate maps from two or more projected coordinate systems into a GIS (ESRI, 2007a)." However, thanks to GIS's automatic operation, users are able to perform this process without understanding each and every mathematical operation behind individual map projections.

3) Data analysis and modeling

Figure 2 demonstrates the procedures of analysis and modeling, which consist of three

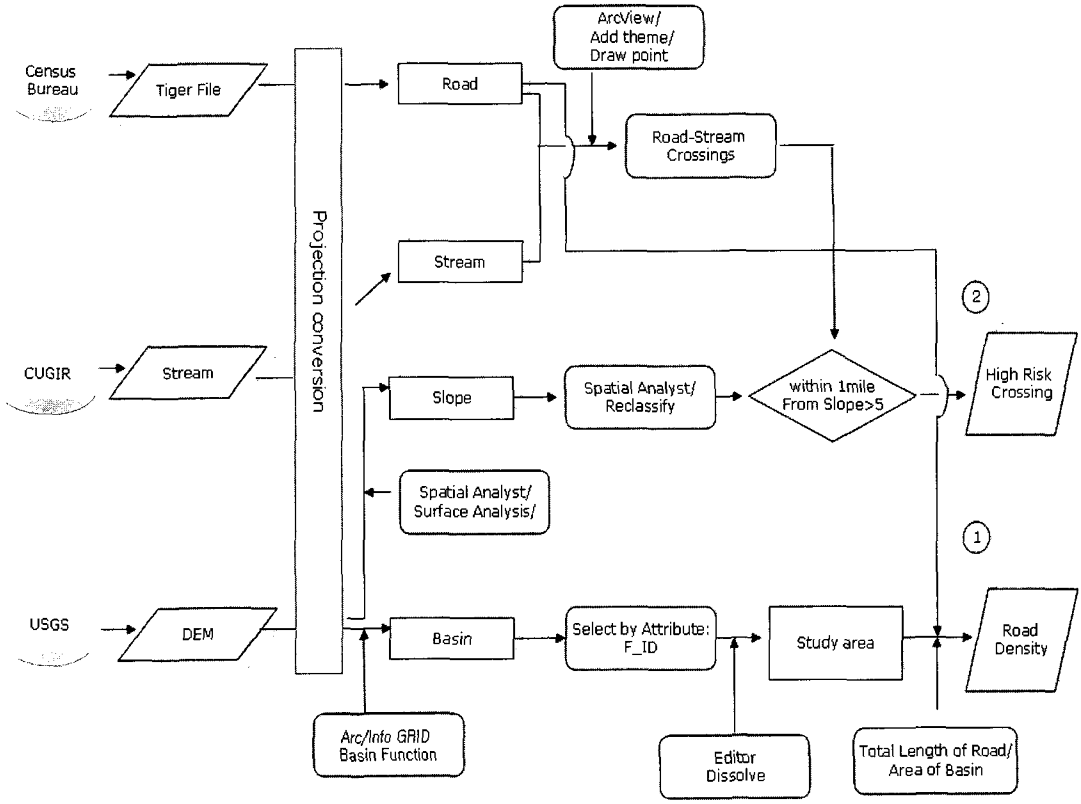

Figure 2. Flow chart of analysis methods

major parts: delineating the study area; calculating the road density; and finding the high risk road-stream crossings.

The first step of analysis is delineation of the study area, which is preparatory to the full-scale modeling procedures of calculating road density and finding high-risk crossings. The result is shown on Figure 3. This study area is a sub-basin of the Buffalo River-Eighteenmile Creek Watershed, which is located at the western end of New York State and covers an area of approximately 732 sq. mi. The watershed drains to Lake Erie through the Buffalo River, Eighteenmile Creek and a number of smaller streams directly tributary to Lake Erie between Sunset Bay at the mouth of Cattaraugus Creek and the mouth of Scajaquada Creek at the Niagara River in the City of Buffalo. As shown in the flow chart of Figure 2, extraction of Basins from the DEM is conducted using the Arc/Info GRID Basin function. The total number of sub-basins is 5442.

As the next step of data analysis and modeling, road density is calculated. Human activity has been speeded up by the increase of accessibility. Roads are the most common form of access in these days. Roads enable people to access to nature in order to extract the natural resources, build towns, develop industrial sites and exchange resources, capital, and labor from place to place. However, it is no wonder that roads can also disturb the natural landscape and bring

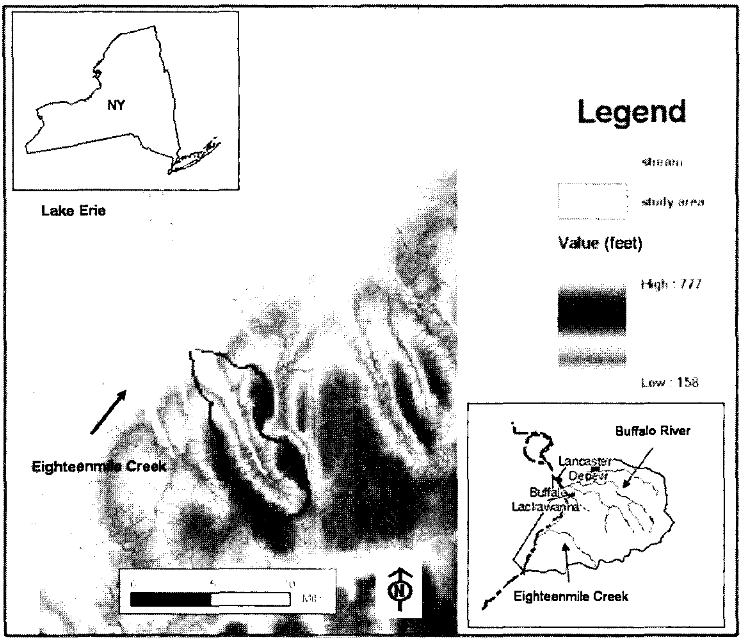

Figure 3. The result of delineating the study area: Note that the blue-lined stream shows the course of the Eighteenmile Creek and a black-lined area is a sub-basin which is selected as a study area. The inset in the upper left corner is the New York State map and the inset in the lower right corner showing the Buffalo River-Eighteenmile Creek Watershed.

undesirable effects to species that require large tracts of undisturbed land. Many species of wildlife (such as wolves, falcons, and owls) require large unbroken stretches of habitat to survive. In the western United States, wolves disappear when there is more than 1 mile of road per square mile of forest (ESRI, 2007b).

The idea of this analysis, "Calculation of Road Density" was started from Trombulak and Frissell's (2000) work. As they put it, "the construction and maintenance of roads had been one of the most widespread forms of modification of the natural landscape during the past century" (Trombulak and Frissell, 2000). They note the importance of understanding the scope of the ecological effects of roads. Several negative effects of roads on biodiversity were reviewed: mortality from road construction; mortality from collision with vehicles; modification of animal behavior; disruption of the physical environment; alteration of the chemical environment; spread of exotic species; and increased use of areas by humans. Therefore, a measure of access or road density can be an important indicator of the various stresses on biotic integrity in both terrestrial and aquatic ecosystems.

Road density, an indication of the health status of watershed is calculated by the simple formula below (equation 1):

Road density (mile/ mile^2)=Total Length of Road (mile) / Total Area of Basin (mile^2) ...... (eq. 1)

In order to calculate the road density of the Eighteenmile Creek sub-basin, the total length of road and the total area of basin are obtained from opening both attribute tables and summarizing each value. At this point, the unit of measurement should be noted. As mentioned in section 4.1, Data Documentation, the original unit is feet, which have to be adjusted to miles and square miles for road length and basin area, respectively. The total length of road is 45.37 miles and the total area of basin is 39.28 miles^2. Therefore, the road density of the study area is 1.16 miles/miles^2.

The final step of the data analysis and modeling in this study is to find high-risk crossings. In 1997, the United States Department of Agriculture (USDA) Forest Service published "The Water/Road Interaction Technology Series" to identify information and methods for the hydrological aspects of developing, operating, and managing forest roads (USDA Forest Service, 1997). This research has led to a widely accepted set of water quality Best Management Practices (BMP) that reduce the sediment impacts to streams which are derived from road and trail. It also serves to save time and cost, minimize erosion, and increase the safety of users on roads and trails. The specific data analysis of this study, "find high-risk crossings" is adopted from a part of this research.

Commonly, road-stream crossings and ditch-relief culverts are the sites of ongoing or potential erosion (USDA Forest Service, 1998). Erosion from the failure of these structures can be a cause of significant impact to the aquatic and riparian ecosystem, even places far from the initial failure site. Thus, continuous maintenance and replacement of these areas is positively required. However, financial resources for maintaining and upgrading the existing structures are limited. Therefore, it is necessary that those sites that pose the highest risk to aquatic and riparian ecosystems be located and treated to reduce environmental risks. In this unit, we will call these sites "high-risk crossings."

A substantial amount of research has been dedicated to the environmental risk assessment of road-stream crossings. The USDA Forest Service (1998) reviewed eight road-stream crossing assessment techniques which are currently used throughout the United States. According to this report, the factors which have an impact on the road-stream crossings are various, and include hydrologic factors (i.e. ponding, culvert size, culvert blockage, potential blockage), landuse and landscape factors (i.e. channel gradient, upstream fill height, hillslope surface gradient, channel width, entrenchment), soil type, topography and vegetation (USDA Forest Service, 1998). In spite of these various factors, only the slope(%) is taken into account as a factor in this study in order to simplify and reorganize the appropriate curriculum content considering the target grade level (8th grade). At first, road-stream crossings are drawn by Add Theme / Draw Point in. The total number of crossings is 59. Second, the slope is extracted from the DEM by Spatial Analyst / Surface Analysis and reclassified to 4 classes; 0-1, 1-5, 5-10, above 10. Thirdly, 15 high risk road-stream crossings are derived from Select by Location, which is buffering within 1 mile from the area where the slope is greater than 5%(See Figure 4).

5. Lessons and Their Assessment

1) Sequence of lessons

Based on the multi-dimensional environmental

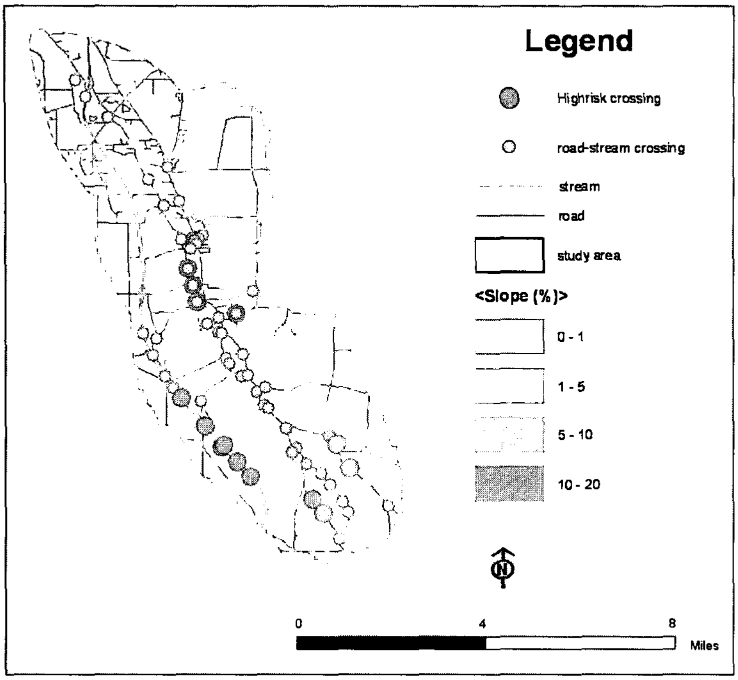

Figure 4. High risk road-stream crossings

education framework with GIS and geographical perspectives, a series of lessons were created for actual classes through the practical curriculum development process including data documentation, data manipulation, and data analysis. The curriculum outline can be found in Appendix A. (Worksheets for the actual classroom implementation are also available through the corresponding project website, http://www.buffalo.edu/~boaechun/env_edu/) This curriculum is designed as 7 classes of 90-minutes each. Thus, the block time schedule is preferable for continuity and concentration of activity instead of the traditional 45-minute schedule. The topics of contents include: Introduction to GIS I; Introduction to GIS II; Watershed address; Road -density; Road-stream crossing; Final Project; and Presentation. As the final step of these lessons, presentation to the local community or participation in the policy making process is highly recommended in order to enhance the students' citizenship. For teacher's information, a list of resources including VHS, Internet, and books is provided in Appendix B.

This multi-dimensional environmental education framework will be strengthened and revitalized through GIS. Moreover, GIS is expected to enable students to have an environmental ethic because it would help foster a transformation in their self-esteem and value systems, which is the ultimate goal of geographic and environmental education.

For example, in the unit five, "Finding the High Risk Crossing" a teacher may guide students to find out the potential hazards of a road-stream crossing and the factors that might affect a high risk crossing. Besides, going a step forward, students will understand the necessity of the continuous inventory and assessment of the road- stream crossing as a reasonable solution to address this problem. In other words, students are required to understand that the first step is locating sites with potential impacts on aquatic and riparian environments for possible treatment. However, it is much more important for the student to observe the fact that with restricted budgets for road maintenance and repair, locating those sites that have the greatest likelihood of causing adverse impacts, the high risk-crossings is necessary to prioritize the expenditure of funds in order to reduce or eliminate risks (USDA Forest Service, 1998). Like every decision we make in our social life, thus, students will learn that effective strategies for addressing environmental problems will require compromises between the stakeholders and between the polar interests of economic growth and environmental quality. This is the moment to show how decision making enters a new phase when it is integrated with GIS for spatial analysis.

Through this unit, students will experience how spatial analysis actually works by manipulating the real data of the real world using GIS. So, students are expected to shift the emphasis from "knowledge building" by lecturing and taking notes in the traditional classroom in the traditional learning theories to "community building" by practicing, participating and communicating in the constructivist learning theories.

2) Activities and assessment

In this unit, we developed a series of worksheets for 7 classes of 90 minutes each under one topic, "studying the environment of Eighteenmile Creek." The prominent characteristic of these worksheets is the format combining activity with assessment. Also, the worksheet is composed of a set of evaluations dividing the formative evaluation. In the rest of this section, we will think over the issues on the activities and assessment which might be brought up during the actual classroom implementation with

Table 3. The examples to assess the three domains, following Bloom's taxonomy

Domain	Example of question
Cognitive domain	• Can students define the meaning of watershed? • Can students calculate the road-density? • Can students understand the importance of connecting their own watershed with community? • Can students interpret the result of road-density by comparison with that of other watersheds? • Can students find other factors which affect the road-stream crossings?
Affective domain	• Can students achieve environmental sensitivity and environmental ethics? • Can students realize their behavior can affect the environment of their own watershed? • Can students list their possible behaviors in order to protect their watershed?
Psychomotor domain	• Can students use the basic functions of GIS software listed below? □ Identify □ Pan □ Zoom in/zoom out □ Measure □ Select • Can students delineate their own watershed? • Can students calculate the area of watershed by using GIS?

connecting to Bloom's taxonomy.

Arguably, Bloom's taxonomy is relatively out of date but still serves as an important reference for administrators and teachers at all levels of education providing a structure which can be used to build curriculum materials that take learners more deeply into the area of study. As a matter of course, it is neither the only way to write the educational objectives nor even a completely valid one. Since 1956, it has been reinterpreted in different ways and it is still under debate and challenge. However, the taxonomy takes on renewed importance in the information or knowledge age (Houghton, 2003).

Also in this unit development, Bloom's taxonomy (Bloom, 1956) was adopted to write the learning goals and to build the items of the formative evaluation in each worksheet. Following Bloom's taxonomy, the examples to assess the three domains such as cognitive, affective, and psychomotor are shown below table 3.

6. Conclusion

The study described in this paper is in progress. In this phase, the paper has narrowed down to an investigation of a theoretical and conceptual framework through literature reviews, a desirable model-building for geographic and environmental education and a sample curriculum development. Through this interdisciplinary environmental education of their own watershed, GIS can be expected to provide students with temporal and spatial perspectives, which illuminate environmental ethics, broaden a point of view, and develop environmental behaviors.

However, contrary to the ground plan, an interdisciplinary approach within the unit leaves some room for improvement, which seems to give relative consequence to the social studies even though mathematics, geomorphology, and ecology are employed in classes 3, 4, and 5, respectively. Other disciplines such as biology, economics, and chemistry are expected to be integrated for a more desirable curriculum. Also, connecting with community should be reviewed as an important component in geographic and environmental education because its educational effects are expected to swing upward rapidly when we involve the community in environment education.

On the other hand, a corresponding project website, Environmental Education with GIS within Community (http://www.buffalo.edu/~boaechun/env_edu/) has been developed so that students and instructors can easily download and share the information and curriculum. As the next phase of the project, the website will be expanded and data and maps are also available through this website. Currently, various methods of data collection through the classroom observation, field notes, in-depth interview with teachers and students, focus group meeting, surveys and document collection are ongoing. Based on data analysis from this experimental study, the research will investigate the effectiveness of this multi-dimensional approach to environmental education in the near future.

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Appendix A. Overview of the curriculum

Unit	Unit title	Big Question	Technology/Skills	Concepts/Content	Learning Objectives
1	Introduction to GIS I	What is GIS? And why GIS?	• Search the Internet and find a good application of GIS in the real world.	• GIS • Geographical perspectives	• Define the meaning of GIS. • Understand the usefulness of GIS.
2	Introduction to GIS II	Then, how can we use GIS as a smart user?	• Add and remove a layer. • Click and see the various functions of GIS.	• Smart user	• Get familiar with GIS functions using the 'learning-by-doing' method. • Rethink each function and evaluate it.
3	Watershed address	You know your ZIP code, but you don't know your HUC code?	• Access to the EPA website and find one's own watershed address. • Locate upstream watershed and downstream watershed.	• Watershed and sub-watershed. • Connecting to elevation. • Connecting to scale.	• Understand the hierarchical order of HUC. • Predict the impact of the water pollutant to other watersheds. • Evaluate the motto, 'Think Globally, Act Locally.'
4	Road-density	Why is road-density important?	• Add layers as needed to analyze the road-density. • Open attribute table and calculate the sum of total length of roads and total area of watershed using ArcView's spreadsheet function. • Calculate the road-density in one's own watershed.	• Human impact on the environment • Cultural perception of environment	• Compare the road-density in one's own watershed with that of other watersheds. • Observe the pattern of the road-density in New York Sate, US, and other country. • Identify the pattern of road and connect it to the cultural perception of US
5	Road-stream crossings	What occurs at a road-stream crossing?	• Find crossing points of road and stream • Draw points using 'Add theme' in ArcView. • Classify the road-stream crossings by the slope (%). • Define the high risk crossing. • Select road-stream crossings within 1 mile from the high risk crossings using buffer distances.	• Environmental influences on human behaviors	• Compare the road-stream crossings in one's own watershed with that of other watersheds • Observe the pattern of the road-stream crossings in New York Sate, US, and other country. • Find other environmental influences on the road-stream crossings
6	Final project	How can we take part in our community?	• Use PowerPoint to make a project poster.	• Citizenship • Public participation	• Synthesize the findings from this project • Draw a conclusion based on the observations and evaluate one's own conclusion • Rethink the concept of the ownership of community
7	Presentation	How can we present our findings to the pubic effectively?	• Expand PowerPoint skills to make an oral presentation material.	• Government • Civics	• Apply the GIS map-making skills, Internet searching skills, and other skills. • Evaluate the limitations of the project. • Suggest recommendations for future.

Appendix B: Resources for this curriculum

Type	Resources
1. VHS	• Explore Your World: GIS in K-12 Education, 18 minutes, ESRI • GIS-10: Introduction to GIS-A Workshop, 390 minutes (http://www.amproductions.com/videos/gis/gis10-1.html, last accessed 05/01/2007)
2. Internet	• Know your watershed (http://www.ctic.purdue.edu/KYW/glossary/whatisaws.html, last accessed 05/01/2007) • Surf your watershed (http://www.epa.gov/surf/, last accessed 05/01/2007) • ESRI' school GIS website (http://www.esri.com/k-12, last accessed 05/01/2007) • ESRI EdUC (Educator's User Conference) (http://www.esri.com/gisgedconf, last accessed 05/01/2007) • Intro Materials and Cool Downloads for Schools and Libraries (http://www.esri.com/industries/k-12/docs/material.html, last accessed 05/01/2007) • Environmental Statistics Group- Hydrologic Unit Project (http://www.esg.montana.edu/gl/huc/, last accessed 05/01/2007) • State of Environment Reporting (from the Ministry of Environment, British Columbia, Canada) (http://www.env.gov.bc.ca/soerpt/3habitat/roadsglance.html, last accessed 05/01/2007)
3. Book	• Alibrandi, M., 2003, *GIS in the Classroom: Using Geographic Information Systems in Social studies and Environmental Science*, Heinemann, Portsmouth, NH. • Brewer, C. A., 2005, *Designing Better Maps: A Guide for GIS Users*, ESRI Press, Redlands, CA. • English, K. Z. and Feaster, L. S., 2003, *Community Geography: GIS in Action*, ESRI Press, Redlands, CA. • Green, D. R. (ed.), 2000, *GIS: A Sourcebook for Schools*, Taylor & Francis Inc., New York. • Ludwig, G. S. and Audet, R. H., 2000, *GIS in Schools*, ESRI Press, Redlands, CA. • Malone, L., Palmer, A. M. and Voigt, C. L., 2002, *Mapping Our World: GIS Lessons for Educators*, ESRI Press, Redlands, CA. • Malone, L., Palmer, A. M. and Voigt, C. L., 2003, *Community Geography: GIS in Action Teacher's* Guide, ESRI Press, Redlands, CA. • Sommer, S. and Wade, T., 2006, *A to Z GIS: An Illustrated Dictionary of Geographic Information systems*, ESRI Press, Redlands, CA.

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Notes

1) HUC is the acronym of hydrologic unit code consisting of two to eight digits based on the four levels of classification (i.e., regions, sub-regions, accounting units and cataloging units) in the hydrologic unit system. Through this system, all US watersheds have a proper name and corresponding numbers. In short, the HUC code means the watershed address. To see more information about HUC, visit USGS Water Resources website, Hydrologic Unit Maps (http://water.usgs.gov/GIS/huc.html, last accessed 05/01/2007)

2) ArcView GIS is one of today's most popular desktop geographic information system (GIS) software programs from ESRI (Environmental Systems Research Institute, Inc.). The primary merit of ArcView is that the ArcView interface consists of windows that present information in different ways and ArcView's graphical user interface (GUI) is located along the top of the active window, which makes ArcView user-friendly. Thus, a user doesn't need to learn by heart every command language in the DOS situation. Instead, a user only points and clicks the icon in order to act on a his/her command.

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