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ABSTRACT

This paper describes an inquiry-based, student-centered mathematics, science, and technology curriculum guide. It features activities addressing such environmental science topics as groundwater modeling, water filtration, soil permeability and porosity, water temperature and salinity, and quadrant studies. Activities are organized so that the concepts and techniques are first developed in the classroom, then reinforced in the schoolyard. The concepts are then carried out into the field, the Pine Barrens, or other parts of the ecosystem. This structure encourages the learner to discover the scientific principle and test it, thereby performing individual research. Results are reported from a survey of teachers, non-formal science educators, and students who had completed learning activities based on the curriculum guide. (CCM)

An Ecological System Curriculum: An Integrated MST Approach to Environmental Science Education

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Introduction

During the 1990's, developments in the worlds of education and environmental protection have led to a confluence of new initiatives. This provides a unique opportunity for the educational community, with significant implications for teaching and learning about the environment.

The National Science Education Standards (National Research Council, 1996) advocate inquiry-based, student-centered learning environments that go beyond "science as process" to educational systems in which students use reasoning and critical thinking skills to understand the world around them. In addition, the *Curriculum Frameworks for Mathematics, Science and Technology* (New York State Education Department, 1994) and the *Learning Standards for Mathematics, Science and Technology* (New York State Education Department, 1996), stress the integration of mathematics, science and technology (MST) in science teaching and learning.

Since the late 1980's, an appreciation of fragile ecological systems has led to the protection of such areas. Often, appreciation has resulted in the need to seek legal remedies for protection as business, industry and government entities seek to enhance the economic base. With preservation created by legislation and upheld by the courts, these ecosystems are now public lands that can serve as natural learning laboratories.

One area that is now preserved, after a protracted battle between developers and environmentalists, is the Long Island Pine Barrens, an area of approximately 100,000 acres, situated in Suffolk County, the easternmost county on Long Island, New York. This ecosystem is essentially a huge watershed that sits atop an aquifer system that is the sole

supply of drinking water to the three million Long Island residents (Englebright, 1980). In addition, the Pine Barrens is home to diverse and unusual species, many of which are endangered or threatened (Turner, 1994).

The Problem

The effort to preserve the Long Island Pine Barrens, was a grassroots one, initiated and driven by the Long Island Pine Barrens Society, a non-profit organization originally organized to raise educational awareness about the importance and uniqueness of the Pine Barrens, a natural, non-formal science education resource. In 1995, the U.S. Environmental Protection Agency (EPA) provided funding for the development and the dissemination of a curriculum guide for teachers that would serve as a resource for area teachers. The challenge was to develop a document that addressed the standards and frameworks, built upon constructivist teaching and learning principles. Such a guide would encourage students to develop and apply higher order critical thinking and science reasoning as they explore their outdoor "laboratory." A secondary goal, although a more comprehensive one, was to create a curriculum guide that would be easily adaptable to any age learner exploring any ecosystem.

Methodology

The central element in the curriculum guide is a set of lesson plans that generally describe inquiry-based, student-centered MST activities. These activities address environmental science topics such as groundwater modeling; water filtration; soil

permeability and porosity; water temperature and salinity; and quadrat studies. They are organized so that the concept and technique is first developed in the classroom. Reinforcement occurs in the school yard or in front of the school. Finally, they are carried out in the field, i.e., the Pine Barrens or other parts of the ecosystem. Simple materials are used in most cases. This structure encourages the learner to "discover" the scientific principle and then test it, thereby "doing" individual research. It is also constructivist in nature; each activity builds on the learning and understanding previously developed.

Many of the lesson plans provide a "sketch" of the activity. This allows the teacher to easily tailor it to the audience and encourage student participation in the design of the experiments. These characteristics therefore, also encourage the teacher to use the activities as a basis for action research.

In addition to the lesson plans, the guide includes comprehensive science and legislative background sections. It also contains a resource guide with extensive listings of public access areas of environmental interest on Long Island; environmental organizations; print and video resources; and Internet sites.

Following completion in late 1996, the curriculum guide was distributed to Long Island schools. It was also field tested with 185 learners, representing several populations:

- in-service K-12 teachers attending an EPA-sponsored Pine Barrens workshop;
- in-service science, mathematics and/or technology teachers paired with K-6 teachers completing a science research experience at Brookhaven National Laboratory;

- graduate students enrolled in a Science-Technology-Society (STS) course at the State University of New York at Stony Brook, approximately 60% of whom are in-service K-12 teachers;
- non-formal environmental science educators;
- undergraduate students enrolled in an elementary-level science methods at New York University; and
- middle school students (grades 7-9) participating in the Science and Technology Entry Program at Suffolk County Community College, a state-funded program designed to increase the numbers of minority and educationally disadvantaged students to continue to study science, math and technology to prepare for careers in the sciences and the licensed professions. A summary of participants is presented below.

Cohorts of Participants	Number of Participants
In-service teacher attending workshop	23
In-service teacher in science research prog.	9
Graduate student	49
Non-formal science educator	12
Undergraduate student	36
STEP student	56

Results

Teachers attending the EPA workshop spent four hours as learners. They constructed groundwater models, performed porosity tests in the classroom and the school

yard and participated in quadrat studies. The teachers involved in the science research experience at Brookhaven National Laboratory completed these activities and also performed temperature studies in a two-day experience. The Stony Brook at New York University students performed quadrat studies for 2 hours as did the STEP students, who collected samples in the school yard and in the Pine Barrens. The non-formal educators experimented with the field activities for about two weeks.

Following each learning experience, participants were asked to comment on their perception of the value of their participation. In each case, over 90% of learners reported a heightened awareness of their environment. A majority (75%) of the teachers/educators felt empowered to use MST inquiry strategies to teach about the Pine Barrens ecosystem. Students (79%) enjoyed the opportunity to "discover" in the classroom and then apply their new skills and knowledge in the "real world."

Question	Cohort	Yes	No
After completing these activities, you are more aware of the diversity of species in your environment	In-service teacher attending workshop	21	2
	In-service teacher in science research	9	0
	Graduate student	47	2
	Non-formal science educator	12	0
	Undergraduate student	33	3
	STEP student	50	6

I understand the value of MST inquiry activities in teaching (asked of all cohorts other than STEP students)	In-service teacher attending workshop	18	5
	In-service teacher in science research	6	3
	Graduate student	30	19
	Non-formal science educator	10	2
	Undergraduate student	26	10
I enjoyed discovering science concepts and then using them to do experiments in the Pine Barrens	In-service teacher attending workshop	18	5
	In-service teacher in science research	9	0
	Graduate student	28	21
	Non-formal science educator	11	1
	Undergraduate student	34	2
	STEP student	50	6

Implications

The field tests indicate a general level of satisfaction with the program. The next step is to revisit participants to determine if they are using the knowledge that they seemingly acquired and internalized. Are teachers comfortable with MST inquiry-based teaching? Are students comfortable with MST inquiry-based learning? Are both groups continuing to explore the Pine Barrens and other ecosystems?

As explained above, although this guide was developed to study a specific ecosystem, it is applicable to the study of any ecosystem. The major topics are central to the environmental science, and, hence, to the study of the environment any where. It has been

field tested in the urban environment of New York City, awakening students to the diversity of urban park lands. Similarly, it could be easily adapted to a Caribbean island such as Trinidad or a mountainous region such as Colorado. This flexibility makes this approach to MST environmental education a particularly valuable one.

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