THE USE OF INST
LITERACY:

THE USE OF INSTRUCTIONAL TECHNOLOGY IN PURSUING SCIENTIFIC LITERACY: A CASE STUDY OF A FOURTH GRADE TEACHER

By

Gregory Alan Coverdale

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Teacher Education

1996

THE USE OF
LITERA

This study

uctional techn

k a fourth gr

nology-rich c

nderstand ho

ing scientifi

ths.

This study

scribed what a

acher's integrat

ea heavily on

ls and Objec

terpiece of sc

ience curricul

scribes what

sed on the con

Various

ndards. First

OOSE in a

exemplary el

ssons, I provi

emplary scien

ABSTRACT

THE USE OF INSTRUCTIONAL TECHNOLOGY IN PURSUING SCIENTIFIC LITERACY: A CASE STUDY OF A FOURTH GRADE TEACHER

By

Gregory A. Coverdale

This study is a report of an exemplary fourth grade teacher who utilized instructional technology in varied ways to advance her students' scientific literacy. Ms. Brook, a fourth grade teacher in a suburban elementary school, implemented a technology-rich curriculum which actively engaged her students in scientific inquiry. To understand how Ms. Brook and her students utilized instructional technology in pursuing scientific literacy, I observed teaching and learning in her classroom for five months.

This study provided insight into current conceptions of scientific literacy, described what a technology-rich curriculum might look like, and documented one teacher's integration of instructional technology across the science curriculum. The study drew heavily on the dimensions of scientific literacy described in the Michigan Essential Goals and Objectives for Science Education K-12 (MEGOSE). MEGOSE is the centerpiece of science education in Michigan schools. It helps K-12 teachers frame their science curriculum, and drives the state's science assessment program. MEGOSE also describes what K-12 schools need to do in order to promote scientific literacy and is based on the concept that science education is for all students.

Various sections of the study were also framed by the National Science Education Standards. First, using the Standards' definition of scientific literacy helped situate MEGOSE in a national context. Next, the Standards helped frame this study's focus on an exemplary elementary science teacher. Using the Teaching Standards to frame data analysis, I provided evidence that Ms. Brook epitomized the Standards' description of an exemplary science teacher.

Finally, this study

nology in pursuing sc

nsides combined with th

rmation allowed them

Finally, this study described how fourth grade students utilized instructional technology in pursuing scientific inquiry. Their participation in three technology episodes combined with their frequent use of the Internet to access and share scientific information allowed them to extend "real-world" learning to a global context.

In memory of Fred (

Fred loved the challeng

and he touched the l

From Fred I lea

of

Dedication

In memory of Fred Calhoun, my high school chemistry teacher and mentor.
Fred loved the challenge of working with students on their journey through life,
and he touched the lives of thousands of students during his teaching career.
From Fred I learned to love science, and that the ultimate reward
of teaching is in nurturing young minds.

To Margaret, I th

in the excitement y

this study possible

period of time

To all members c

my sincere thanks.

schedules to assist

My decision to p

helped sustain n

grateful. You

graduate stud

encouraged me to follo

Although many

in particular Cur

always reminded n

and Tena Harri

My background

of doctoral stud

classrooms. Hov

study. I thank a

ACKNOWLEDGEMENTS

To Margaret, I thank you for opening your classroom to me, and allowing me to share in the excitement you bring to teaching. Your trust in me and support of my work made this study possible. The opportunity to work with you and your students over an extended period of time was one of the most enriching experiences of my professional career.

To all members of the "Jefferson" Elementary School faculty and administration, I give my sincere thanks. You were extremely helpful to me and often took time from your busy schedules to assist me as I learned the culture of the school.

My decision to pursue doctoral work was fully supported by my family, and their support helped sustain me throughout the long course of study. To my wife Kathy, I am eternally grateful. You made many sacrifices, and gave me the latitude I needed in order to pursue graduate study. To my parents, David and Annabelle Coverdale, you have encouraged me to follow my dreams.

Although many friends have encouraged and supported my work, I would like to thank in particular Curt Erickson, Marcia Fetters, Paul Vellom, and Martial Dembele. You always reminded me I was doing important work. Finally, I sincerely thank Jean Beland and Tena Harrington for helping to edit and format my work.

My background as a classroom teacher had strongly prepared me for the practical aspects of doctoral study - working with students and teachers in elementary and middle school classrooms. However, I was unprepared for the academic and scholarly rigors of doctoral study. I thank all the members of my committee for providing their support and guidance, and for nurturing

Roger Niemeyer for serving

commitment to doctoral study

teaching me about qualitativ

McDiarmid for teaching me

thinking about scientific lite

Deborah Smith for their pat

research. You both provide

guidance, and for nurturing me as I pursued my scholarly interests. I wish to thank Dr. Roger Niemeyer for serving on my initial committee. Your support helped me make the adjustment to doctoral study. I am grateful to Dr. Douglas Campbell for his role in teaching me about qualitative research and how to design my study. I thank Dr. Bill McDiarmid for teaching me more about the foundations of education and pushing my thinking about scientific literacy. Finally, I am grateful to Dr. Jim Gallagher and Dr. Deborah Smith for their patience and willingness to keep me pointed in the right direction. You both provided the support and guidance that a true mentor should.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

This study is a

instructional technolog

Brook, a 4th grade tea

the curriculum which

how Ms. Brook and he

literacy. I observed tea

included fieldnotes fr

analysis of technology

Internet messages.

Focus of the Study

While current

that might lead to stu

known about how cla

incorporate the use of

Thus, I am interested

literacy and specifica

Because scientific inq

use of instructional te

making the connectio

led the central quest

How does an exempl
advance students' sci

The purpose o

elementary teacher u

CHAPTER 1

INTRODUCTION

This study is a report of an exemplary fourth grade teacher who utilized instructional technology in varied ways to advance her students' scientific literacy. Ms. Brook, a 4th grade teacher in a suburban elementary school, implemented a technology-rich curriculum which actively engaged her students in scientific inquiry. To understand how Ms. Brook and her students utilized instructional technology in pursuing scientific literacy, I observed teaching and learning in her classroom for five months. Data included fieldnotes from participant observation, interviews with Ms. Brook, document analysis of technology-rich curricular materials, and document analysis of downloaded Internet messages.

Focus of the Study

While current science policy documents suggest teaching and learning strategies that might lead to students becoming scientifically and technologically literate, little is known about how classroom teachers interpret the documents and how they actually incorporate the use of instructional technology in their teaching for scientific literacy. Thus, I am interested in how elementary teachers think about teaching for scientific literacy and specifically how they utilize instructional technology in teaching science. Because scientific inquiry is a cornerstone of scientific literacy, I focus on Ms. Brook's use of instructional technology in promoting scientific inquiry in her classroom. In making the connection between scientific literacy and the use of instructional technology, I see the central question as:

How does an exemplary elementary teacher utilize instructional technology to advance students' scientific literacy?

The purpose of this study was to develop a richer understanding of how one elementary teacher utilized instructional technology to teach for scientific literacy. The search questions we

scientific literacy, scie

the science teaching.

teachers utilize instruc

Much is known

science education poli

literacy. While ackno

study focuses on exam

current science refo

Science Education K

the National Science

instructional technol

Background and R

Americans

Apparently straigh

interact with scient

lives as well as the

the workplace, va

peoples' lives. In

how to use techn

effectively, make

that teachers, st

scientific literac

follows:

> Scientif
> concep
> pation
> include

research questions were designed to assist in telling the story of how Ms. Brook views scientific literacy, scientific inquiry, and how her knowledge and beliefs were enacted in her science teaching. The study also adds to the growing literature on how elementary teachers utilize instructional technology in teaching for scientific literacy.

Much is known about different conceptions of scientific literacy, and current science education policy documents clearly delineate specific dimensions of scientific literacy. While acknowledging that different conceptions of scientific literacy exist, this study focuses on examining two particular views of scientific literacy that are described in current science reform initiatives: the Michigan Essential Goals and Objectives for Science Education K-12 and the National Science Education Standards. As stated, I use the National Science Education Standards to frame the study's focus on scientific inquiry, instructional technology, and exemplary science teaching.

Background and Rationale

Americans live in a society that has become increasingly technological in nature. Apparently straightforward questions such as "Paper or plastic?" force Americans to interact with scientific and technological issues that affect the well-being of their personal lives as well as the health and well-being of the nation as a whole. From the classroom to the workplace, various forms of technology have become more and more integral in peoples' lives. Increasingly, jobs require more advanced skills, including knowledge of how to use technology in the workplace. Workers need to be able to think critically and creatively, make decisions, and solve problems (NRC, 1996). Thus, it is becoming vital that teachers, students, and the American populace in general achieve a higher level of scientific literacy. The National Science Education Standards define scientific literacy as follows:

> Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. It also includes specific types of abilities. In the National Science Education

Standards, the
22)

This definition of scien

tested in order to be s

in science education r

In order to ma

economically with fo

scientifically and tec

two Germanys, the

European Commun

nature (America

scientifically and t

the global econon

It is a commonly

and economic w

200, 1992; Ben

citizens to make

confront them

Standers Cre

that reads:

> Vista
> by th
> Co
> mo
> sc

> Standards, the content standards define scientific literacy. (NRC, 1996, p. 22)

This definition of scientific literacy argues that specific knowledge and abilities are needed in order to be scientifically literate. Thus, teaching for scientific literacy is central to science education reform and should be a goal of all schools in America.

In order to maintain a free and democratic society, and to effectively compete economically with foreign countries, Americans need to become much more scientifically and technologically literate than they are at present. The reunification of the two Germanys, the disintegration of the former Soviet Union, and the expansion of the European Community have spurred an economy that is becoming more and more global in nature (America 2000, 1992). Other countries are investing heavily to create scientifically and technologically literate citizens (NRC, 1996). To maintain its stature in this global economy, America needs a highly educated, scientifically literate population. It is a commonly-held belief by politicians and educators that citizens' personal, social, and economic well-being are inextricably linked to a high level of education (America 2000, 1992; Benavot, 1992). Without attaining scientific literacy, it will be difficult for citizens to make informed decisions about scientific, technological, and social issues that confront them in newspapers and magazines every day. For example, "California City Considers Creationism Teaching" is a headline from a recent *Los Angeles Times* article that reads:

> Vista, Calif. - A nationally watched debate that may ultimately be resolved by the Supreme Court has captivated this normally quiet San Diego County community, as a Christian majority on the city's education board moves toward a policy mandating the teaching of creationism in public schools (Glynn & Muth, 1994, p. 1058).

It is critical that citizens have the ability to make informed decisions about such issues and it is also clear that scientific literacy involves more than just scientific knowledge. Citizens must have the reading and writing ability to analyze issues and communicate their thoughts with others (Glynn & Muth, 1994).

Current scienc

inextricably interw

Science Education K-

NSES describe what

distinguish the term te

study. Students use ir

pose scientific inqu

understanding of tech

educational technolo

capable of utilizing va

solve problems, and c

Why is scient

argues that the world

humans utilize science

to make decisions abo

effects of new techno

the misuse of techn

vital to the survival of

Having establ

AAAS, 1990, conclu

that America has been

inconceivable that Am

of science and techno

something must be do

recommendations for

and technology togeth

Current science education initiatives view science, mathematics, and technology as inextricably interwoven. While both the Michigan Essential Goals and Objectives for Science Education K-12 (MEGOSE) and the National Science Education Standards (NSES) describe what students should know about technology, the NSES (NRC, 1996) distinguish the term technology from instructional technology, a distinction critical to this study. Students use instructional technology such as computers and other multimedia to pursue scientific inquiry. Thus, if one is scientifically literate, one will have a good understanding of technology, how technology shapes the world, and be able to utilize instructional technology in the process of scientific inquiry. Specifically, students will be capable of utilizing various types of instructional technology to retrieve information, solve problems, and collaborate on scientific issues with colleagues throughout the world.

Why is scientific literacy important? Science for All Americans (AAAS, 1990) argues that the world's economic and environmental destiny is dependent on how wisely humans utilize science and technology. Through science, citizens not only can learn how to make decisions about the use of technology, but also assess the applicability and effects of new technologies as they emerge. While many global problems exist as a result of the misuse of technology, the use of technology to generate solutions to problems is vital to the survival of the human species.

Having established a rationale for scientific literacy, Science for All Americans (AAAS, 1990) concludes that most Americans are not scientifically literate. Considering that America has been and is a world leader technologically, it seems almost inconceivable that Americans rank so far below their foreign counterparts in knowledge of science and technology (Benavot, 1992; Stevenson & Stigler, 1992). Concluding that something must be done, Science for All Americans (AAAS, 1990) provides recommendations for the study of science that weave knowledge of science, mathematics, and technology together.

Conceptions of Scien

In chapter one

central to this study:

Each term is develope

means to be scientific

instructional technol

Following is a brief o

and describes two cur

K-12 schools.

Michigan Es

MEGOSE is t

K-12 teachers frame t

program. MEGOSE

scientific literacy and

The document is curr

learning in Michigan

and be utilizing the d

> The primary p
> **scientific liter**
> essential for fu
> (p. 3)

This conception of sc

that extends beyond m

definition or complet

that scientific knowle

different activities or

applications of real-w

As students be

construct new scienti

Conceptions of Scientific Literacy

In chapter one, I present an overview of three of the important terms that are central to this study: scientific literacy, scientific inquiry, and instructional technology. Each term is developed more fully in chapter two, with specific examples of what it means to be scientifically literate, what traditional scientific inquiry looks like, and how instructional technology is being used in elementary classrooms across America. Following is a brief overview of scientific literacy which defines the terms listed above and describes two current conceptions of scientific literacy being utilized in Michigan's K-12 schools.

Michigan Essential Goals and Objectives for Science Education K-12

MEGOSE is the centerpiece of science education in Michigan schools. It helps K-12 teachers frame their science curriculum, and drives the state's science assessment program. MEGOSE also describes what K-12 schools need to do in order to promote scientific literacy and is based on the concept that science education is for all students. The document is currently being used as a model for the reform of science teaching and learning in Michigan and, therefore, classroom teachers might be expected to know about and be utilizing the document. MEGOSE defines scientific literacy as follows:

> The primary purpose of K-12 science education, therefore, must be **scientific literacy** - an understanding of those aspects of science that are essential for full participation in a democratic society - for **all students.** (p. 3)

This conception of scientific literacy calls for a depth of understanding of science content that extends beyond mastery. To understand an idea requires more than memorizing a definition or completing a "cookbook" set of activities. Students should be able to use their scientific knowledge in real-world contexts, and to apply their knowledge to different activities or situations. In using scientific knowledge, students learn to develop explanations of real-world phenomena.

As students begin to ask questions and develop solutions to problems, they construct new scientific knowledge that helps them make sense of their natural world.

Finally, students lea

and justifying argum

knowledge, and see

1991). Knowledge

describes students n

Many of the teachin

technology. Examp

R3. Describ

R8. Show h
apply in

R9. Describ

These dimensions o

the analysis of the c

The concept

VECOSE in several

students, that learnin

developing a rich

based on important a

different forms, that

and during the schoo

develop in the early s

literacy (NRC, 1996,

lifelong endeavor.

This concept

beyond that of memor

person should be able

Finally, students learn to reflect on their own scientific knowledge. This involves making and justifying arguments, describing limitations of science processes and/or their own knowledge, and seeing relationships among **science, technology,** and **society** (MDE, 1991). Knowledge of technology and technological issues is implied in MEGOSE as it describes students' need to see connections between science, technology, and society. Many of the teaching objectives listed in MEGOSE specifically promote learning about technology. Examples of these objectives are listed below:

R3. Describe ways in which technology is used in everyday life.

R8. Show how common themes of science, mathematics, and technology apply in real-world contexts.

R9. Describe the advantages and risks of new technologies. (p. 148)

These dimensions of scientific literacy presented in MEGOSE provide a framework for the analysis of the central problem of this study.

National Science Education Standards

The conception of scientific literacy defined in the NSES is similar to that of MEGOSE in several ways. It is grounded in the philosophy that science is for all students, that learning science is an active process, and that scientific inquiry is essential in developing a rich understanding of science and the natural world. The NSES are also based on important assumptions; that scientific literacy has different degrees and takes different forms, that the degree of one's scientific literacy develops over a lifetime and not just during the school years, and that important attitudes and values about science develop in the early school years and help shape a person's development of scientific literacy (NRC, 1996). Thus, development of scientific literacy must begin early, and is a lifelong endeavor.

This conception of scientific literacy also requires a depth of understanding beyond that of memorization of science facts and procedures. A scientifically literate person should be able to ask questions and derive answers about everyday experiences, escribe, explain, and

science-related article

person can identify sc

opinions that are scien

be scientifically liter

based on evidence and

In defining scie

scientific inquiry. Be

made the NSES def

> Scientific inqu
> natural world
> from their wo
> they develop
> an understand
> multifaceted
> examining bo
> known; plann
> of experimen
> data; propos
> communicati

How students condu

standards and I exp

exemplary science t

process of scientific

scientific inquiry an

promoted in Ms. Br

Both the NS

science and technol

scientific literacy. T

_______. Becaus

idea on the NSES

The use of "t
"instructiona

describe, explain, and predict about one's natural world, and read with understanding science-related articles in the popular news media. Scientific literacy implies that a person can identify scientific issues at the local, state, and national levels and formulate opinions that are scientifically and technologically informed (NRC, 1996). In doing so, the scientifically literate person should be able to evaluate the strength of arguments based on evidence and reach appropriate conclusions based on the evaluation of evidence.

In defining scientific literacy, the NSES place much emphasis on the process of scientific inquiry. Because development of scientific inquiry is central to this study, I provide the NSES definition of inquiry below:

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (NRC, 1996, p. 23)

How students conduct scientific inquiry is described in detail in the NSES content standards and I expand on those ideas in chapter two. In describing Ms. Brook as an exemplary science teacher who utilizes instructional technology in teaching students the process of scientific inquiry, this study describes the role of instructional technology in scientific inquiry and how the NSES conception of scientific inquiry compares with that promoted in Ms. Brook's classroom.

Both the NSES and MEGOSE acknowledge the close relationship between science and technology, and include knowledge of technology as a component of scientific literacy. The NSES also differentiate the terms technology, and instructional technology. Because Ms. Brook's use of instructional technology is central to this study, I draw on the NSES definition of instructional technology:

> The use of "technology" in the NSES is not to be confused with "instructional technology," which provides students and teachers with

exciting tool
science. (NR

Interpret this defin

computers to includ

data equipment. Li

supporting software

laser disks, etc.

In contrast to

the goal of technolog

NRC, 1996, p. 24).

relationship is descr

Technology
both scientif
the natural w
moreover, te
p. 24)

Thus, becoming scie

and technology, how

technology in scient

Discussion of Resea

The research

technology might pl

scientific inquiry is p

technology-rich clas

science teacher, and

confirmed by my o

science coordinator.

well as observed how

supplies.

> exciting tools - such as computers - to conduct inquiry and to understand science. (NRC, 1996, p. 24)

I interpret this definition of instructional technology to extend well beyond just computers to include many forms of multimedia tools such as CD-ROM technology, video equipment, live cable television network capability, the Internet, and a variety of supporting software including hypermedia, application software, simulation software, video disks, etc.

In contrast to instructional technology, knowing about technology means knowing the goal of technology is to "make modifications in the world to meet human needs" (NRC, 1996, p. 24). In the NSES view, science and technology are closely related. This relationship is described below:

> Technology and science are closely related. A single problem often has both scientific and technological aspects. The need to answer questions in the natural world drives the development of technological products; moreover, technological needs can drive scientific research. (NRC, 1996, p. 24)

Thus, becoming scientifically literate involves knowing the relationship between science and technology, how each affect the natural world, and being able to utilize instructional technology in scientific inquiry (NRC, 1996).

Discussion of Research Questions

The research questions in this study are centered around the role instructional technology might play in teaching for scientific literacy in elementary classrooms, how scientific inquiry is promoted through using instructional technology, and what a technology-rich classroom looks like. They also focus on Ms. Brook as an exemplary science teacher, and her role in promoting scientific inquiry in her classroom. The study is informed by my own professional experience as a classroom teacher and elementary science coordinator. I have utilized instructional technology in my own classroom as well as observed how my colleagues utilize instructional technology in their various disciplines.

As an experie

make my own scienc

asking, "How can I m

students?" My own

dynamic in meeting

analysis of current s

reforming science e

learner's depth of un

scientific literacy, st

knowledge and be a

Clearly, this concep

be taken into consid

in schools.

Informed by

How does an exem
advance students' s

Elements focusing

1. How does this el
technological lite

2. How does this el
inquiry?

3. How does this el

4. How has this ele
in the classroom?

5. What makes this

Elements focusing

6. What do "technol

7. What teaching str
instructional tech

As an experienced teacher I have always been keenly interested in how I might make my own science teaching more effective. I have always challenged myself by asking, "How can I make science more rewarding, relevant, and interesting to my students?" My own use of instructional technology with K-12 students has been one dynamic in meeting that challenge. However, it has become evident to me through my analysis of current science reform documents and doctoral study that a crucial element in reforming science education is in thinking about the learner as well as the teacher. A learner's depth of understanding involves more than student mastery of facts. To attain scientific literacy, students must work collaboratively in their development of scientific knowledge and be able to use that knowledge in real-world contexts (MDE, 1991). Clearly, this conception of science learning and how it relates to scientific literacy must be taken into consideration by classroom teachers as they implement science curriculum in schools.

Informed by the above discussion, I view the central question of the study as:

How does an exemplary elementary teacher utilize instructional technology to advance students' scientific literacy?

Questions focusing on the teacher:

1) How does this elementary teacher view scientific literacy and its connection to technological literacy?

2) How does this elementary teacher utilize instructional technology to promote scientific inquiry?

3) How does this elementary teacher view teaching and learning?

4) How has this elementary teacher prepared herself for utilizing instructional technology in the classroom?

5) What makes this teacher an exemplary elementary science teacher?

Questions focusing on curriculum:

6) What do "technology-rich" instructional units look like?

7) What teaching strategies did this elementary teacher employ when utilizing instructional technology?

How did this element
existing science curri

Framed by conc

research questions are c

curriculum, scientific lit

new scientific knowled

While teachers' use of in

throughout the last deca

Cuban, 1993). Also, g

sporadic at best (Rowe,

teacher who frequently

technology in doing so

exemplary science teac

the central feature of t

developing a case tha

utilizing instructional

challenge? How doe

literacy and children'

What does a

complement it? Th

the curricular episo

Flamingowatch was

land-use issues of t

researched the

and students from

Buchmann

knowledge in orde

8) How did this elementary teacher incorporate instructional technology into new or existing science curricula?

Framed by conceptions of scientific literacy and instructional technology, the research questions are concerned with the teacher, the technology-rich science curriculum, scientific literacy, and scientific inquiry. How does this elementary teacher view scientific knowledge, scientific literacy, and the use of instructional technology? While teachers' use of instructional technology in elementary classrooms has grown throughout the last decade, it is still by no means a commonly employed teaching strategy (Cuban, 1993). Also, given that science teaching in elementary schools in general seems sporadic at best (Rowe, 1983), it seems a fairly unique situation to find an elementary teacher who frequently teaches science, and who frequently utilizes instructional technology in doing so. As I will discuss later, Ms. Brook epitomizes the qualities of exemplary science teaching described in the NSES, and thus I focus on her teaching as the central feature of this case. Thus, it seems relevant to ask questions that assist in developing a case that uncovers who this teacher is. What are her motivations for utilizing instructional technology? How has she prepared herself for such a pedagogical challenge? How does she view her use of instructional technology vis-a-vis scientific literacy and children's learning? How does her teaching promote scientific inquiry?

What does a technology-rich science unit look like and how does one decide how to implement it? This study examines Ms. Brook's implementation of three technology-rich curricular episodes, the largest being the Flamingowatch electronic fieldtrip. Briefly, Flamingowatch was a real-time student investigation of the flora, fauna, geology, and land-use issues of the Great Rift Valley in East Africa. Students participated in the field trip, researched the region, and shared their findings in a live, interactive electronic forum with students from another school.

Buchmann (1984) argued that teachers need to be equipped with content knowledge in order to have "stuff" to teach. Given that most science curricula with which elementa

ow does Ms. I

What technolog

tilizing techn

quipment rega

ontent know

rovided in th

eachable mo

nstructional

mplementin

pecifically

what it asks

The

echnology

ore instru

Many teach

ntegrating

eachers la

n their cla

look like w

Th

t also sug

Provident

eachs to

escribed

which elementary teachers interact do not contain "technology" as part of the content, how does Ms. Brook decide what technology-related curricula to use and when to use it? What technology "stuff" has Ms. Brook utilized in her science teaching? This aspect of utilizing technology-rich curricula is very important, especially given Buchmann's argument regarding content knowledge and Shulman's (1986) description of pedagogical content knowledge (a review of the literature on pedagogical content knowledge is provided in chapter two). Knowing content helps teachers to recognize and capitalize on teachable moments (Buchmann, 1984). This study examines how Ms. Brook brings instructional technology to bear on science content and issues, thus designing and implementing science curricula that is technology-rich. The study also examines specifically what this science/technology curriculum looks like in terms of its content and what it asks students to do.

The research questions also focus on <u>how</u> Ms. Brook utilizes instructional technology in teaching science. Teachers frequently lament that they would like to utilize more instructional technology but are unsure of how to proceed and what to proceed with. Many teachers have a classroom computer as well as district goals and objectives for integrating technology into the curricula. But frequently, and for a variety of reasons, teachers lack the <u>know how</u> to utilize instructional technology confidently and effectively in their classrooms. How does Ms. Brook do it and what does the teaching and learning look like when she does?

This chapter establishes a rationale for the efficacy of pursuing scientific literacy. It also suggests that while guidelines outlining the dimensions of scientific literacy are prevalent in the literature, there is still a fair amount of confusion about what it actually means to be scientifically literate. Therefore, current conceptions of scientific literacy are described in detail in chapter two.

Scientific literac

els. Many reform ef

For example, about twen

ative projects for the

sponsored by the Nation

educators, university pe

from industry w

ly is meant by scie

e in order that the

How should teachers ar

the quest for univers

questions, but as Amer

schools to provide stu

effective citizens.

In seeking to c

questions, this study e

ing scientific lite

e that the use of

students strive to ma

students' perspectives

throughout the schoo

-based, techno

While science

acy for a nation's

CHAPTER 2

REVIEW OF THE LITERATURE

Scientific literacy for all students is the primary goal for science education at all levels. Many reform efforts are underway nationwide to help schools achieve that goal. For example, about twenty-five states are currently implementing Statewide Systemic Initiative projects for the systemic reform of science, mathematics, and technology. Sponsored by the National Science Foundation, these projects bring together K-12 educators, university personnel, state and national government personnel, and special interests from industry with the common goal of science education reform. But what exactly is meant by scientific literacy? How do elementary students become scientifically literate in order that they may be knowledgeable and effective contributors to society? How should teachers and students in elementary schools utilize instructional technology in the quest for universal scientific literacy? There are no easy answers to these questions, but as America becomes increasingly technology-based, it seems critical for schools to provide students with the scientific and technological knowledge to become effective citizens.

In seeking to contribute to the body of knowledge that helps address the above questions, this study examines how an elementary teacher and her students go about pursuing scientific literacy. The classroom chosen for the study is technology-rich in the sense that the use of instructional technology plays a key role in how the teacher and students strive to make sense of the world around them. The study looks closely at insiders' perspectives regarding the science teaching and learning that has occurred throughout the school year. It also examines how a teacher and her students use a project-based, technology-rich curriculum to pursue scientific literacy.

While science as a discipline is centuries old, the concept of universal scientific literacy for a nation's citizenry is relatively new. Schools' use of instructional technology pursuing scientific lit

classrooms only in the e

study in relation to other

The literature reveals th

literacy, while not rare,

relationship between sci

might be integrated into

This literature re

attempts to clarify wha

cornerstone of current s

conceptions of scientif

Science Education Sta

Education Standards' c

relationships between

classrooms, this litera

Section A: Current C
Section B: Introduct
Section C: Introduct
Section D: Teacher

Secti

A central ther

scientific literacy mu

has evolved from re

education. Policy-m

mean to be scientif

conceptions of scien

science students shou

in pursuing scientific literacy is even newer, with most electronic technology reaching classrooms only in the early 1980's. The purpose of this literature review is to situate this study in relation to other work that has been done in science and technology education. The literature reveals that the use of instructional technology in pursuing scientific literacy, while not rare, is still in its infancy. Thus, there is much to be learned about the relationship between science teaching and learning and how instructional technology might be integrated into the process.

This literature review examines recent conceptions of scientific literacy, and attempts to clarify what is meant by the term scientific literacy, especially as it is the cornerstone of current science education reform documents. In reviewing current conceptions of scientific literacy, I also review the National Science Education National Science Education Standards' view of scientific inquiry, and the National Science Education Standards' definition of instructional technology. In attempting to examine the relationships between scientific literacy and the use of instructional technology in classrooms, this literature review is organized into five sections:

•Section A: Current Conceptions of Scientific Literacy;
•Section B: Introduction to Technology;
•Section C: Introduction to Instructional Technology;
•Section D: Teacher Knowledge, Expert Teaching, and Exemplary Science Teaching.

Section A: Current Conceptions of Scientific Literacy

A central theme in the current literature on science education reform is that scientific literacy must be achieved by the majority of, if not all, citizens. Although the term evolved from reform efforts in the 1960's, it has never achieved a consistent definition. Policy-makers and educators today still struggle with the question "What does it mean to be scientifically literate?" In this chapter, I provide descriptions of current conceptions of scientific literacy, with specific suggestions about what scientifically literate students should be able to do.

Much of this stu

Objectives for Science I

and the philosophy unde

engineers, and educator

MEGOSE is validated b

practice. MEGOSE sug

scientific literacy to occ

1. emphasize teach coverage. Move conceptual under

2. emphasize learn contexts. Take a view the real wor

3. emphasize scienti that is inclusive a minorities: (p. 4)

4. promote interdisc it should be conne

5. develop a support training, materials exemplary science

According to MEGOSE,

scientifically literate citiz

and complex societal iss

issues, the implementa

scientific literacy in Ame

teaching, and support sys

Teachers, adminis

collaboratively to revise a

curriculum development

textbook revision and ad

current strengths, the 5-

Much of this study is framed by the ideas in the Michigan Essential Goals and Objectives for Science Education K-12 (MEGOSE). The definition of scientific literacy and the philosophy underlying MEGOSE were based on the contributions of scientists, engineers, and educators throughout the United States. Thus, as a science framework, MEGOSE is validated by being based on the latest educational research and scientific practice. MEGOSE suggests that for innovative science teaching and the acquisition of scientific literacy to occur, schools should strive to adopt the following goals:

(1) emphasize teaching for understanding, rather than blanket content coverage. Move away from rote memorization of facts and toward conceptual understanding; (p. 3)

(2) emphasize learning that is useful and relevant to students' real-world contexts. Take advantage of students' prior knowledge of how they view the real world outside of school; (p. 4)

(3) emphasize scientific literacy for all students. Design science curricula that is inclusive and available to all students including females and minorities; (p. 4)

(4) promote interdisciplinary learning. Science does not exist in a vacuum - it should be connected to other academic disciplines; (p. 4)

(5) develop a support system for teachers. Provide teachers with the training, materials, and working conditions that will facilitate exemplary science teaching. (p. 5)

According to MEGOSE, if schools achieve these goals, Michigan students will become scientifically literate citizens capable of making sense of the natural world and dealing with complex societal issues. However, as the introductory paragraph of this section indicates, the implementation of science goals and curricula in the quest for increased scientific literacy in American youth involves wide-ranging change in curriculum, teaching, and support systems.

Teachers, administrators, teacher educators, and policy-makers frequently engage collaboratively to revise and develop curricula for K-12 schools. The catalyst for curriculum development might be a restructuring of a particular curricular department, a textbook revision and adoption process, the hiring of new teachers with new and/or different strengths, the 5-year plan of curriculum revision, etc. Another impetus for curriculum de

such as those

standards. F

better prepare

What

specific curri

process. Wa

is pertinent to

to previous c

effects of nev

general. Stu

developers "c

Ultim

the teachers a

as the gateke

(in Lortie, 19

interested in

the intended

history it see

specifically h

reforms (Wal

In cha

school scienc

definition of

describe in de

of scientific li

literacy.

curriculum development might be to meet or conform to new goals and policy standards such as those established by the Michigan Department of Education or similar federal standards. Finally, curriculum is often revised with academic achievement in mind - to better prepare students for success on statewide standardized tests.

Whatever the purpose for curriculum revision, knowledge of curriculum history in specific curricular domains should be considered in order to inform the decision-making process. Walker (1990) provides several reasons why a knowledge of curriculum history is pertinent to any curriculum development process. For example, knowledge of results in previous curricular reform movements might help predict with more certainty the effects of new curricula on students, the teaching and learning process, and the school in general. Studying the history of past curriculum movements may also help curriculum developers "cut and paste" what was effective and eliminate what was ineffective.

Ultimately, however, the success or failure of any curriculum depends heavily on the teachers and students who occupy classrooms. Teachers commonly view themselves as the gatekeepers in the education process and implement curriculum in ways they deem fit (Lortie, 1975). Similarly, students typically learn what they can or what they are interested in. It is well known that the learned curriculum may bear little resemblance to the intended or the taught curriculum (Walker, 1990). Thus, in studying curriculum history it seems of paramount importance to examine also teaching practice, and specifically how teachers interpret curriculum innovation and implement curricular reforms (Walker, 1990; DeBoer, 1991).

In chapter one, I provided a rationale for scientific literacy as the primary goal of school science. I provided the MEGOSE and National Science Education Standards' definition of scientific literacy, as they frame parts of this study. In this section, I describe in detail the MEGOSE and National Science Education Standards' conceptions of scientific literacy, and contrast them with other current conceptions of scientific literacy.

Michigan Essential G

The purpose o
to design K-12 scienc
described the importa
programs in Michigan
scientific literacy, and
students should be abl

MEGOSE is b
teaching for scientific
All Americans was w
community develop a
schools might look li
the documents provid
students should be ab
eight and twelve. Its
1960's by explicitly s
science learning shou
science teaching has r
activities being tradi
widespread scientific
achievement.

An extensive l
the subject areas and g
of scientific literacy.
literate students are n
large amount of infor

Michigan Essential Goals and Objectives for Science Education K-12 (MEGOSE)

The purpose of MEGOSE is to assist schools and teachers in thinking about how to design K-12 science curricula that promote scientific literacy. In chapter one I described the importance of MEGOSE in playing a central role in the K-12 science programs in Michigan's schools. I also gave an overview of the MEGOSE conception of scientific literacy, and how the authors of MEGOSE view what scientifically literate students should be able to do.

MEGOSE is based on and parallels very closely the recommendations for teaching for scientific literacy provided in Science for All Americans (1990). Science for All Americans was written to help educators and the science education research community develop a shared vision of what science and mathematics education in schools might look like. In combination with Benchmarks for Science Literacy (1993), the documents provide a vision for science education reform and statements of what all students should be able to do in science, mathematics, and technology in grades two, five, eight, and twelve. Its philosophy differs from some science reform programs of the 1960's by explicitly stating that the major objective in pursuing scientific literacy is that science learning should be for ALL students. Implicit in this argument is that traditional science teaching has not served the entire population equally well, with females and minorities being traditionally underrepresented in science classes. If the aim is widespread scientific literacy in a democratic society, this philosophy seems crucial to its achievement.

An extensive list of instructional objectives is provided which is cross-referenced to subject areas and grade levels and is organized around three very specific dimensions of scientific literacy. These dimensions of scientific literacy recognize that scientifically literate students are not necessarily those who have memorized and temporarily stored a large amount of information. "Scientifically literate students know how to: use knowledge, to engage in

specifically outline the

Knowledge

> Nothing is under
> for example, me
> supported by m
> relationships. (p

The authors of MEGOS

characteristics of scient

different kind of know

1) being famili
   and its unity

2) understandin

3) being aware
   mathematic

4) knowing th
   enterprises
   (p. 6)

5) having a c

6) using scie
   social purp

Thus, MEGOSE dre

dimension of scient

understanding idea

as involves havin

concepts and theor

that one needs to fu

Activity

Activity is

ing, constructin

knowledge, to engage in activities, in real-world contexts" (MEGOSE, 1991). Below I specifically outline the three dimensions of scientific literacy described in MEGOSE.

Knowledge

> Nothing is understood in isolation. To **understand** an idea (as opposed to, for example, memorizing a definition) is to see how it is related to and supported by many other ideas; its meaning is bound up in those relationships. (p. 5)

The authors of MEGOSE quote Science for All Americans (1990) in describing six characteristics of scientific literacy. Each of those six characteristics are related to a different kind of knowledge and are listed below:

> 1) being familiar with the natural world and recognizing both its diversity and its unity; (p. 5)
>
> 2) understanding key concepts and principles of science; (p. 5)
>
> 3) being aware of some of the important ways in which science, mathematics, and technology depend on one another; (p. 5)
>
> 4) knowing that science, mathematics, and technology are human enterprises and what that implies about their strengths and limitations; (p. 6)
>
> 5) having a capacity for scientific ways of thinking; (p. 6)
>
> 6) using scientific knowledge and ways of thinking for individual and social purposes; (p. 6).

Thus, MEGOSE drew heavily on Science for All Americans in defining the knowledge dimension of scientific literacy. Having scientific knowledge is a matter of understanding ideas and concepts and seeing the relationships between them. Knowledge also involves having an understanding of the nature of science and technology, the key concepts and theories of science, its historical roots, and developing the habits of mind that one needs to fully participate in and appreciate the scientific domain.

Activity

Activity is the second dimension of scientific literacy and consists of students using, constructing, and reflecting on scientific knowledge. Students are able to use concepts and ideas in a

scientific knowledge ar

community in which sci

each of the three catego

Using Scientific Know

Scientifically l
understand the
types of activi
explanation c
events or obse
enable people

Constructing New S

Scientificall
With scienti
that can be
Scientifical
they encou
scientifical
abilities, se
empirical
text, grap
knowledg
points and
knowledg
(p. 6-7)

In under

describe and ex

solutions to pr

literate studen

learned know

scientific kno

and limitation

be able to ta

science, tech

concepts and ideas in a real-world context. In this dimension, students learn to use their scientific knowledge and skills collaboratively, becoming members of a scientific community in which science is not only studied, but shared with others. Below I describe each of the three categories in the activity dimension of scientific literacy.

Using Scientific Knowledge

> Scientifically literate students and adults can use their knowledge to understand the world around them and to guide their actions. Important types of activities that use scientific knowledge include **description** and **explanation** of real-world objects, systems, or events; **prediction** of future events or observations; and the **design** of systems or courses of action that enable people to adapt to and modify the world around them. (p. 6)

Constructing New Scientific Knowledge

> Scientifically literate students are learners as well as users of knowledge. With scientific literacy comes the ability to **ask questions** about the world that can be answered by using scientific knowledge and techniques. Scientifically literate students can also **develop solutions** to problems that they encounter or questions they ask. In developing solutions, scientifically literate students may use their own knowledge and reasoning abilities, seek out additional knowledge from other sources, and engage in empirical investigations of the real world. They can learn by **interpreting** text, graphs, tables, pictures, or other representations of scientific knowledge. Finally, scientifically literate students can remember key points and use sources of information to **reconstruct** previously learned knowledge, rather than try to remember every detail of what they study. (p. 6-7)

In understanding the world around them, scientifically literate students are able to describe and explain real-world objects, systems, or events. They can design systems or solutions to problems that enable them to modify their natural world. Scientifically literate students are able to ask questions, interpret data, and reconstruct previously learned knowledge. In doing so, they are able to analyze and reflect on their own scientific knowledge. They seek evidence and justifications, and evaluate the strengths and limitations of their own knowledge. In doing so, scientifically literate students may be able to take historical or cultural perspectives as they consider relationships between science, technology, and society (MDE, 1991).

Reflecting on

Scien
on th
justi
emp
show
reve
diffe
cult
rela
scie
kno

Contexts:

Sc
the
sc
as
ch
co
ca
da
h

S

Reflecting on Scientific Knowledge

> Scientifically literate students can also "step back" and analyze or reflect on their own knowledge. One important type of analysis is the **justification** of personal knowledge or beliefs using either theoretically or empirically based arguments. Scientifically literate students can also **show an appreciation** for scientific knowledge and the patterns that it reveals in the world; this often involves seeing **connections** among different areas of knowledge. They may be able to take an **historical and cultural perspective** on concepts and theories or to discuss institutional relationships among **science, technology,** and **society.** Finally, scientifically literate students can **describe the limitations** of their own knowledge and scientific knowledge in general. (p. 7)

Contexts: Knowing the Real World

> Science is about the real world. Scientifically literate students can use their knowledge in many different real world **contexts**. In the physical sciences, the specification of contexts often focuses on **phenomena**, such as motion, electromagnetic interactions, or physical, chemical, and nuclear changes in matter. In the life sciences, earth sciences, and technology, contexts are often described in terms of **systems** and **subsystems**, such as cells, organisms, ecosystems, atmospheric systems, or technological devices. There are other contexts, such as those associated with art, history, or ethics, in which use of scientific knowledge is quite limited. (p. 7).

Scientific knowledge is used in natural, human, and symbolic contexts (MDE, 1991). No student has ever seen an atom, and few have seen a volcano or many other scientific phenomena, other than in pictures or diagrams. Thus they can use representations about phenomena to understand them in the symbolic context. MEGOSE focuses heavily on students learning to apply their scientific knowledge in a real-world context, that is, in being able to see the connection between science and everyday life situations.

Each dimension of scientific literacy is represented in much more detail in the data analysis coding table in chapter three. It should also be mentioned here that in this definition of scientific literacy, it is the cumulative process of science study that leads to one becoming scientifically literate. In other words, at each successive grade level, students become more and more scientifically literate, as they are achieving the objectives for scientific literacy for that grade.

To summ

...the views scien

...that the memor

...individual en

Science Matter

The part

...the current conc

...achieve it. In th

...ill-defined s

...for them being

...media is being s

The auth

...today's world, s

...them to particip

...about scientific

...ience. The au

...scientists and ed

...this estimat

...educators and s

Hazen a

...scientific comm

... Of cours

...philosophical u

...their own scien

...connects th

...their est

...necessity fo

To summarize, the conception of scientific literacy contained in MEGOSE is one that views science as important to all students, emphasizes depth of understanding rather than the memorization of content, and views the process of science as a social rather than an individual endeavor.

Science Matters: Achieving Scientific Literacy

The participation of citizenry in the discourse of science is a theme common to all the current conceptions of scientific literacy; the differences among them lie in how to achieve it. In their 1991 book Science Matters: Achieving Scientific Literacy, Hazen and Trefil defined scientific literacy as the knowledge you need to understand public issues. For them, being able to understand and contextualize science as presented by the news media is being scientifically literate.

The authors rationalized the importance of scientific literacy by arguing that in today's world, significant scientific and policy issues must be considered by citizens in order to participate in the country's discourse. Being able to understand national debate about scientific and technological issues is crucial and thus, one must be scientifically literate. The authors highlighted their role in effecting scientific literacy by arguing that scientists and educators have generally failed to prepare a scientifically literate populace. In this estimation, the authors are in agreement with many past and present science educators and scholars.

Hazen and Trefil (1990) postulated that doing science should be left to the scientific community while using science is what the average citizen needs to know how to do. Of course, this view differs from the MEGOSE view of scientific literacy. The philosophical underpinning of MEGOSE is that students will not only be able to construct their own scientific meaning, but will do so in the context of doing the type of science that connects their prior understanding to real-world meaning. Hazen and Trefil stressed that in their estimation, the ability to participate in the national debate does not involve the necessity for a detailed, specialized knowledge, but rather a broader, general nowledge of scie

mportant for three

l. ivic - that is th

2. esthetic - the u
Understanding

3. ntellectual con
understanding o

In this conception

eaching paradigm

rgument was tha

mastered, will ren

knowledge that al

eighteen core con

concepts.

The New York T

In this 199

literacy is not a m

This position is co

the authors of Sci

acquiring a broad

knowledge of "pl

argument. Flaste

science is not ta
superstition sup
many people do

I find Flaste's arg

in this review. T

Flaste (1991, sa

to the public in

knowledge of scientific concepts. Developing this broad scientific knowledge is important for three reasons:

1. civic - that is the "effective citizen" argument;
2. aesthetic - the unity between how different things in the natural world work. Understanding how the laws of nature affect our lives;
3. intellectual connectedness - understanding the Zeitgeist - having an intellectual understanding of why certain ideas are the important ones of our times.

In this conception of scientific literacy, the authors argued against the current science teaching paradigm that is organized around separate science disciplines. Their major argument was that there is an identified and static body of scientific knowledge that, if mastered, will render citizens scientifically literate. There is a central core of scientific knowledge that all citizens should attain. This body of knowledge is organized around eighteen core concepts of science. These concepts help connect all specific scientific concepts.

The New York Times Book of Scientific Literacy

In this 1991 conception of scientific literacy, Flaste (1991) argued that scientific literacy is <u>not</u> a matter of memorizing science facts, vocabulary, and scientific principles. This position is congruent with the authors of <u>Science for All Americans</u>. However, like the authors of <u>Science Matters</u>, Flaste argued that scientific literacy is achieved by acquiring a broad familiarity with important scientific issues of the day and that a knowledge of "plain English," not specialized vocabulary is needed. In making this argument, Flaste cited studies that show:

•science is not taught at all in many U.S. high schools;
•s uperstition supersedes scientific thought for many people;
•many people do not trust science as a way of knowing about the natural world.

I find Flaste's argument above to be questionable, but I represent his argument accurately in this review. Thus, journalism has a role to play in society's quest for a "truer view." Flaste (1991) saw the role of journalism as one which distills the issue and then presents it to the public in a succinct and interesting way. In effect, it demystifies science for the public. Th

unfamiliar

scientific i

F.

this scien

drawing i

philosoph

listen an

about the

that by m

and sugg

F

understan

importan

revealed

achieve

divergen

Science-

I

discuss

here P

and sci

of all sc

public. The journalistic portrayal of scientific concepts is also free of jargon, makes unfamiliar concepts familiar and palatable, and minimizes the role of mathematics in scientific issues (Flaste, 1991).

Flaste recognized, however, that one must develop "habits of thought" in order to think scientifically. Challenging one's assumptions, being intelligently skeptical, and drawing informed conclusions are all skills needed to be scientifically literate. This philosophy differs from the Science Matters conception of scientific literacy in that Hazen and Trefil suggested that "asking and answering questions" as a way of knowing about the natural world was valid and necessary. In Science Matters, the authors argued that by merely attaining the static body of knowledge, one becomes scientifically literate and suggest that it is the knowing, not the application of knowledge which is important.

Finally, Flaste argued that scientific literacy comes from one's ability to read and understand science in the news. What is in the news is representative of what is important to society at any given time. Clearly, the rationale for scientific literacy revealed in both the above positions bears similarities to that found in MEGOSE. How to achieve scientific literacy and what it means to be scientifically literate is where the divergence of positions occurs.

Science-Technology-Society: Perspectives on Scientific Literacy

If the rationale for scientific literacy established in this study bears merit, then a discussion of the Science-Technology-Society (STS) reform movement seems relevant here. Producing a scientifically literate population, one that is prepared to debate issues and solve problems related to science and technology, seems to be a fairly universal goal of all science programs hoping to contribute to students' scientific literacy. Thus, the STS approach to science curriculum and teaching contributes to the current conceptions of scientific literacy.

What is STS and how did it originate? The term STS was coined by John Ziman in his 1980 book Teaching and Learning About Science and Society (in Solomon and

Aikenhead. Eds

of the 1980's. Y

& Barth (1992

how STS is cur

In his 19

became one of

name. Gallagh

that they projec

processes of sc

The implicatio

literacy in citiz

science paradig

In 198

position by clo

became broad

environmental

between scien

Many
educa
scient
1980's

scient
and so
in the
substa
proces
logical
techno

By the

the science e

Projects. Wak

raised by the

Aikenhead, Eds, 1994). As a science curriculum movement, STS is very much a product of the 1980's. Yager (1990, 1993), Rubba (1987), DeBoer (1991), Bybee (1993), Waks & Barchi (1992), and Solomon & Aikenhead (1994) discuss perspectives on STS and how STS is currently contributing to science teaching and learning.

In his 1971 article "A Broader Base for Science Teaching," James Gallagher became one of the first to propose that science education be organized around an STS theme. Gallagher was particularly critical of the sixties curriculum projects. He argued that they projected a limited view of science, focusing on the conceptual schemes and processes of science, to the detriment of the social aspects of science (DeBoer, 1991). The implications of Gallagher's argument were that in considering the pursuit of scientific literacy in citizens, the <u>society</u> part of STS needed much more emphasis than the current science paradigm was providing.

In 1982, the National Science Teachers Association (NSTA) adopted a similar position by closely tying their conception of scientific literacy with the STS theme. STS became broadly defined by its emphasis on <u>humanistic</u>, <u>value-oriented</u>, and <u>environmental</u> concerns (DeBoer, 1991). The official NSTA position on the connection between scientific literacy and STS was as follows:

> Many of the problems we face today can be solved only by persons educated in the ideas and processes of science and technology. A scientific literacy is **basic** for living, working, and decision making in the 1980's and beyond....
>
> The goal of science education during the 1980's is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision-making. The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual networks, and process skills which enable the individual to continue to learn and think logically. This individual both appreciates the value of science and technology in society and understands their limitations. (DeBoer, 1991).

By the mid-1980's, those promoting STS considered the movement to be cutting edge science education, both in its own right and in its relationship to other reform projects (Waks & Barchi, 1992). A variety of STS models emerged during this period, backed by the NSTA and implemented in schools (Rubba, 1987).

Yager's (

the problems ass

paradigm contras

paradigms influe

Each prev

thing in common

necessary. For n

science teaching

associated with t

1. An extre
students.

2. Even tho
do not at

3. Interest i

4. Creativit
in tradit

5. There is
literate c

In descri

1990) argued t

society. In this

lives of student

seen by Yager (

Yager's (1993) analysis of science, society, and technology provides insight into the problems associated with traditional science teaching and how the traditional paradigm contrasts with the STS approach. This is a useful analysis, because both paradigms influence how one might think about scientific literacy and how to achieve it.

Each previous conception of scientific literacy analyzed in this study has one thing in common: in pursuing scientific literacy, reform of traditional science teaching is necessary. For many, the origin and growth of STS has been in response to traditional science teaching (Yager, 1993). Yager (1993) described the most critical problems associated with traditional science teaching as:

1. An extremely high number of misconceptions held by even the best science students. Inability to use the science they learn;
2. Even though many students perform well on tests and pass courses, over 90% do not attain scientific literacy;
3. Interest in science and further science study declines across the K-12 years;
4. Creativity, as a central component of the process of science, is usually thwarted in traditional science teaching;
5. There is no evidence that traditional science teaching produces scientifically literate citizens.

In describing the relationships among science, technology, and society, Yager (1993) argued that STS means using technology as the connector between science and society. In this way, the applications of science become closer and more relevant to the lives of students. Following is an abbreviated contrast of traditional and STS classes as seen by Yager (1993, p. 149).

Table 1 Contras

T
Concepts are rea mastered for a te
Students see scie scientists posses
Students see tea information;
Students have fe

In reviewing th

the goals of SF

reform efforts

section, I addr

Histori

criticism of its

Holstein and

issues and an

of a heated c

It was not the

suggestion of

away from sc

Another arg

be taught (D

systematic

discipline-ba

Table 1 Contrast of Traditional & STS Classes

Traditional	STS
Concepts are really bits of information mastered for a teacher test;	Students see concepts as personally useful;
Students see science processes as skills scientists possess;	Students see science processes as skills they can use;
Students see teacher as a purveyor of information;	Students see teacher as a facilitator;
Students have few original ideas;	Students seem to effervesce with ideas (Yager, 1993).

In reviewing this contrast, it seems that the STS position is not radically different from the goals of SFAA and MEGOSE. What then differentiates STS from other science reform efforts? Where is it heading as a modern-day reform movement? In the next section, I address these questions.

Historically, as STS developed during the 1970's and early 1980's, there was little criticism of its interpretation of scientific literacy (DeBoer, 1991). However, in 1982, Hofstein and Yager argued forcefully that science should be organized around social issues and an STS approach rather than around the disciplines of science. This touched off a heated controversy between STS advocates and more traditional science educators. It was not the STS emphasis on societal issues that discomforted traditionalists, but the suggestion of organizing science concepts around social issues. This was seen as a flight away from science, consistent with an anti-science mood in the nation during that period. Another argument against STS that is still prevalent today is that the basics simply do not get taught (DeBoer, 1991). The contention was that an STS approach would not provide a systematic framework for presenting science content. The debate over STS versus discipline-based science continued throughout the 1980's but the debate subsided without resolution o

scientific li

STS

were much

of STS em

classroom

science he

materials

STS goal

most scie

instructor

professio

scientific

The Nati

I

resolution of the issues. Thus, STS remains a viable, if controversial, conception of scientific literacy today.

STS has also experienced difficulties in its implementation, although the problems were much more pronounced in its inception than they are today. When the philosophy of STS emerged in the early eighties, its goals were embraced by many schools and classroom teachers. Its focus on relevant societal issues, values, and environmental science held intuitive appeal to educators. The problem was that textbooks and curricular materials did not integrate the STS approach. Thus, teachers attempting to teach to the STS goals had to improvise and construct much of their own STS curriculum. While most science textbooks today infuse STS into the "normal science," STS has not become institutionalized. A parallel problem is that many, if not most, science teachers lack the professional preparation to teach from an STS perspective. Thus, STS as a vehicle for scientific literacy occurs sporadically in U.S. schools.

The National Science Education Standards

In chapter one, I gave a brief overview of the National Science Education Standards view of scientific literacy, including specific definitions of scientific literacy, scientific inquiry, and instructional technology. In this chapter, I review the National Science Education Standards conception of scientific literacy, first giving an overview of the National Science Education Standards, then describing the process of scientific inquiry and how that process contributes to scientific literacy.

The goal of the National Research Council's National Science Education Standards is to define scientific literacy, to create a vision for citizens to strive for in their pursuit of scientific literacy, and to provide a common set of standards to guide science teaching and learning in schools. The rationale for scientific literacy provided in the National Science Education Standards mirrors that provided in the Michigan Essential Goals and Objectives for Science Education K-12 (MDE, 1991), and in Science for All Americans: Project 2061 (AAAS, 1990). The escalating need for Americans to become informed decisio

bearing on their

science knowled

cornerstone of sc

The conc

bears much rese

philosophy and

Literacy. Like

for school scien

1. experien
natural

2. use app
(p. 13)

3. engage
technol

4. increas
underst
(p. 13)

The goals abov

goals implies t

interesting scie

knowledge bas

the learning c

As stated in ch

literacy as som

scientific liter

Standards are

emphasize tha

early years of

informed decision-makers about scientific and technological matters that have a direct bearing on their lives, as well as the intrinsic fulfillment and satisfaction offered by science knowledge were cited as reasons for the promotion of scientific literacy as the cornerstone of science programs in schools (NRC, 1996).

The conception of scientific literacy in the National Science Education Standards bears much resemblance to that in MEGOSE in that both documents are compatible in philosophy and concepts with Science for All Americans and Benchmarks for Science Literacy. Like MEGOSE, the National Science Education Standards are based on goals for school science which are intended to educate students who are able to:

1) experience the richness and excitement of knowing about and understanding the natural world; (p. 13)

2) use appropriate scientific processes and principles in making personal decisions; (p. 13)

3) engage intelligently in public discourse and debate about matters of scientific and technological concern; (p. 13) and

4) increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers. (p. 13)

The goals above define a scientifically literate society (NRC, 1996). Implementing these goals implies that schools will have students who are actively-engaged in relevant and interesting scientific inquiry. Through scientific inquiry, students will establish a knowledge base for understanding science and together with their teachers will be a part of a learning community focused on learning science, and becoming scientifically literate. As stated in chapter one, the National Science Education Standards describe scientific literacy as something developed over a lifetime, not just in K-12 schooling. Nor is scientific literacy considered an "all or nothing" phenomenon (NRC, 1996). The standards are intended to foster continual development of scientific literacy. They emphasize that critical attitudes and values towards science are established in students' early years of schooling.

Content Standa

In chapt

scientific inquir

of the K-4 conte

study. I frame i

scientific inqui

Scientif
natural
from th
they de
an unde
multifa
examin
known
of expe
data; pr
commu

The definition

through doing

scientific ideas

definition com

scientific litera

engaging inve

consistent with

Standards hav

The Na

Math (Con

While this sec

K-4 content s

Content Stan
Content Stan
Content Stan
Content Stan
Content Stan
Content Stan
Content Stan

Content Standard K-4: Science as Inquiry

In chapter one, I provided the National Science Education Standards definition of scientific inquiry. The National Science Education Standards elaborate on that definition in the K-4 content standards. Because this section on scientific inquiry is central to this study, I frame it by again providing the National Science Education Standards' view of scientific inquiry:

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (p. 23)

The definition above describes several components of scientific inquiry, and states that through doing scientific activities, students develop knowledge and understanding of scientific ideas and how scientists study the natural world. The key words in this definition correlate to several of the MEGOSE subpoints of the three dimensions of scientific literacy. Asking questions, proposing answers, explaining and predicting, designing investigations, and communicating the results of investigations are all consistent with MEGOSE. Thus, MEGOSE and the National Science Education Standards have a similar view of the process of scientific inquiry.

The National Science Education Standards include knowledge of science as inquiry (Content Standard A) in the science content that K-4 students should know. While this section of my review focuses on content standard A, scientific inquiry, other K-4 content standards include:

• Content Standard B:	Physical Science (p. 123);
• Content Standard C:	Life Science (p. 127);
• Content Standard D:	Earth and Space Science (p. 130);
• Content Standard E:	Science and Technology (p. 135);
• Content Standard F:	Science in Personal and Social Perspectives (p. 138); and
• Content Standard G:	History and Nature of Science (p. 141).

A

as the so

several s

inquiry o

purpose

students

inquiry

- e

S

question

world. A

stories

-

I

whenever

investig

- s

S

with the

Deter

computer

and quan

-

E

explanat

Taking

Although the standards emphasize scientific inquiry, they do not recommend this as the sole approach to science teaching. Also, although scientific inquiry consists of several skills and abilities, the National Science Education Standards do not advocate that inquiry consists of a step-by-step sequence or a singular "scientific method." Rather, the purpose of Standard A is to describe some abilities of scientific inquiry appropriate for students in grades K-4 (NRC, 1996). Below, I summarize the abilities for scientific inquiry listed in Content Standard A.

• Ask a question about objects, organisms, and events in the environment.

Students should be able to ask questions about their environment, and answer the questions by utilizing their scientific knowledge and their observations of their natural world. Answers also derive from students seeking information from a variety of reliable sources and their own investigations.

• Plan and conduct a simple investigation.

In the primary grades, investigations are based on students' systematic observations. By fourth grade, students should be able to conduct a more elaborate investigation by gathering, organizing, and interpreting data.

• Employ simple equipment and tools to gather data and extend the senses.

Students learn how to observe, measure, cut, connect, switch, turn on and off, hold, tie, and hook (NRC, 1996). Students progress from using equipment such as rulers, thermometers, watches, spring scales, and beam balances to microscopes, calculators, and computers. The ability to use this range of equipment allows many options for observing and quantifying elements of students' natural world.

• Use data to construct a reasonable explanation.

Even in the early grades, students should be able to use data to formulate explanations, learn what constitutes evidence, and evaluate the strength or merit of data in making judgments or drawing conclusions. Based on their use of data, students propose explanations which th

observations of others

• Communica

Students deve

of others. In some fo

This communication

This section

Content Standard A

content standard A

Having taught K-8

very similar scienc

In its description o

present much that

approach to teach

Education Stand

scientific inquiry

The National Sc Technology

In chapte

Standards defini

established that

acknowledge tha

Study is the NRC

> As used
> distingui
> differenc
> and the g
> human ne
> Educatio

explanations which they check against scientific knowledge, their experiences, and the observations of others.

• **Communicate investigation and explanations.**

Students develop the ability to critique and analyze their own work and the work of others. In some form, students should communicate about their scientific knowledge. This communication could be spoken, drawn, or written.

This section summarized the National Science Education Standards description of Content Standard A: Science as Inquiry. In analyzing the skills and abilities described in content standard A, I feel this is a very traditional description of scientific inquiry. Having taught K-8 science for twenty years, I have used science textbooks that advocated very similar science processes in describing "the scientific method," or scientific inquiry. In its description of scientific inquiry, the National Science Education Standards do not present much that is new to science education. This study focuses on Ms. Brook's approach to teaching for scientific literacy, which, according to the National Science Education Standards, subsumes scientific inquiry. Thus, in chapter four I examine scientific inquiry as it plays out in Ms. Brook's classroom.

The National Science Education Standards View of Technology and Instructional Technology

In chapter one, I gave a brief overview of the National Science Education Standards definition of the terms "technology," and "instructional technology," and established that both MEGOSE and the National Science Education Standards acknowledge the close relationship between science and technology. Appropriate to this study is the NRC's stance on technology, and its relationship to science:

> As used in the National Science Education Standards, the central distinguishing characteristic between science and technology is a difference in goal: The goal of science is to understand the natural world, and the goal of technology is to make modifications in the world to meet human needs. Technology as design is included in the National Science Education Standards as parallel to science as inquiry. (NRC, 1996, p.24)

This vision of s

Americans ho

Science Educa

technology by

> The us
> not to
> studen
> inquir

I reiterate tha

n Ms. Brook

This

addressed tha

scientific lite

still much w

review the l

n scientific

scientific lit

and becaus

would not

has descri

This is critic

scientific li

In t

has provid

knowledg

view of s

This vision of science and technology is very similar to that in Science for All Americans: how humans utilize technology to shape the world they live in. The National Science Education Standards also differentiate the terms 'technology' and 'instructional technology' by stating:

> The use of "technology" in the National Science Education Standards is not to be confused with "instructional technology," which provides students and teachers with exciting tools - such as computers - to conduct inquiry and to understand science. (NRC, 1996, p. 24)

I reiterate that the purpose of this study is to examine the role of instructional technology in Ms. Brook's pursuit of scientific inquiry and scientific literacy.

This concludes the literature review on scientific literacy. The review has addressed the definition of scientific literacy, and analyzed current conceptions of scientific literacy. Given the amount of work that has been done in this field, there is still much we need to know about how to achieve scientific literacy. In Section B, I review the literature to define technology, technological literacy, and how the two relate to scientific literacy. It is necessary to relate technology and technological literacy to scientific literacy because one could pursue scientific literacy without using technology, and because teachers who do utilize instructional technology could pursue goals that would not necessarily lead to technological or scientific literacy with their students. I also describe how current instructional technologies are being implemented in schools, as this is critical to my analysis of how teachers utilize instructional technology in pursuing scientific literacy.

Section B: Introduction to Technology

In this section, I present an analysis of the nature and principles of technology. I also provide a rationale for the use of technology in schools, different conceptions of technology, and examples of how schools have implemented technology to date. This review of the literature on technology is intended to inform this study about how elementary

looks like.

Alth

classroom.

This is dem

Americans

Science fo

The Natur

Sc

way. Tec

materials,

to change

technolog

is using t

important

Understan

Science f

Te

science ga

science an

problems,

example,

Why many

knowlede

technology

elementary teachers utilize instructional technology in teaching science, what that process looks like, and how that contributes to students' scientific literacy.

Although this study focuses on the use of instructional technology in Ms. Brook's classroom, I believe it important to place this technology and its use in a broader context. This is done effectively by the influential science policy document Science for All Americans. In the next section, I analyze SFAA's view of technology.

Science for All Americans: Perspectives on Technology

The Nature of Technology

Science for All Americans describes technology, in the broadest sense, in this way: "technology extends our abilities to change the world: to cut, shape, or put together materials; to reach farther with our hands, voices, and senses. We use technology to try to change the world to suit us better" (AAAS, 1990, p. 23). However, the use of technology has always produced results that were both advantageous and unpredictable. In using technology, civilization has reaped the bad with the good. Thus, it is just as important to anticipate the effects of technology as to advance its capabilities. Understanding the use of technology versus its effects is a theme consistent throughout Science for All Americans.

Technology is frequently, and narrowly defined as "applied science." How does science get applied? Science for All Americans posits engineering as the glue that binds science and technology. Through engineering, knowledge of science is used to solve problems. This "problem-solving" frequently means the design of new technology. For example, the development of the computer has led to our ability to use the computer to study many scientific problems. Creating mathematical models to assist in studying worldwide weather and climatic patterns is an example of how mathematics, science, and technology merge.

Aga

defining a p

solve the p

example, in

steps" hav

existing te

Principles

W

operates

materials

need to co

deciding

social, ec

consider

based en

of proble

the gene

C

people

process

water sup

and en

increase

Again, engineering is central to technological advance. Engineers are engaged in defining a problem and in designing a solution to the problem. By using technology to solve the problem, it is not uncommon for new technologies to be developed. For example, in the attempt to improve upon computer memory, new types of "memory chips" have emerged and new systems of managing memory have been developed. Thus, existing technology is used to develop new technology.

Principles of Technology

What are the principles of technology? Technology has "game rules," that is, it operates under certain constraints. For example, physical laws and physical properties of materials affect how an engineer might design a problem solution. Engineers typically need to consider a material's flexibility, electrical conductivity, strength, etc., when deciding which materials to use. Other types of constraints include economic, political, social, ecological, and ethical. An engineer strives to design problem solutions that consider all constraints and reach compromises among them. An example of a school-based engineering problem might be represented by a typical Odyssey of the Mind-type of problem. Designing a better mousetrap within a specific budget epitomizes this type of engineering compromise.

Clearly, however, the above example simplifies the problems engineers face in the compromise process. There is not a perfect solution to any problem. Thus, communities grapple with the difficulty of making reasonable decisions based on available data. This process is typified by the following dilemma: Is it economically feasible to bolster the water supply in the western U.S. by building desalination plants? Political, economic, and environmental constraints would need to be measured when considering how to increase the amount of fresh, usable water to western states. An alternative to desalination might be damming more rivers. Engineers could easily do both, but what constraints would affect the outcome? Knowing how to think about the effects of engineering and technology is important in the process of becoming scientifically literate.

As various systems are designed and built by engineers, benefits will accrue and unintended effects of the technology will emerge. Some of these effects may prove harmful. For example, the design and production of computers, especially the personal computer, has greatly increased productivity in the workplace. However, the dangers of carpal tunnel syndrome and exposure to electronic emissions from the computer's monitor have emerged as serious health risks to computer users. What should be done? That is another engineering problem. However, being knowledgeable about this particular technological problem, and being able to analyze such a problem exemplifies what it means to be technologically literate.

Many of today's global problems are a result of large-scale technologies. For example, nuclear reactors, agricultural, and industrial practices all benefit civilization but are prone to a variety of problems. However, most citizens own technological devices that also are problematic; that is, technological problems also exist on a smaller scale. Release of CFC's through refrigerator and automobile use are examples of technological problems experienced directly by individuals. The collective concern, of course, is that small-scale problems add up to large-scale problems when taken together. I recently was surprised to read that approximately 10% of the U.S.'s air pollution stems from lawn mowers and other small engines. How to improve upon and possibly regulate the use of small engine devices becomes a matter for citizen concern. Again, all the constraints incumbent upon engineering come into play when considering this type of problem. Knowing how to reach reasonable compromises in the design and implementation of solutions to the small engine problem will require scientifically literate citizens. On another level, citizens may weigh options available to them regarding purchasing mowers and small engine machines as more "non-polluting" models become available.

Technology and Society

Technology has had a tremendous impact on the course of history, and as new technologies emerge, the impact will continue, if not increase. In this vein, it is important reconsider

social char

movements

relationship

directions.

Wh

innovation

determine

the public

potentially

the divers

presenting

protest ag

the engin

the risks.

the U.S.

the need

T

to consider that large technological changes, such as industrialization, are also causes of social change. The reverse view is that social change, such as political or religious movements, has been technology's catalyst. Because of the close, almost inseparable relationship between technology and society, several factors influence technology in both directions.

What factors affect technology? Perhaps the largest influence on technological innovation is the effect of free-market forces. How people react to technology will determine the success or failure of the technology. The benefits of technology as well as the publicity of adverse effects will be considered by citizens. This consideration potentially determines the fate of a technology. In most cases, if the benefits outweigh the adverse aspects of a technology, it will be accepted by society. For example, generating electricity using nuclear power plants continues, despite considerable public protest against it. In deciding to continue with nuclear power, governments have weighed the engineering constraints previously mentioned and have decided the benefits outweigh the risks. In this example, one wonders what would happen should a nuclear reactor in the U.S. malfunction, killing thousands of Americans? Should that scenario ever occur, the need for a scientifically literate citizenry would be paramount in the quest for re-evaluation of the engineering constraints vis-a-vis the production of nuclear generated electricity.

To be scientifically and technologically literate, Americans need to be able to ask the right questions about existing and emerging technologies. Proper decision-making can never be assured, but asking informed questions about technology at least informs the debate. Most questions about technology include asking about factors such as safety issues, cost/benefit analysis, technological alternatives, resources needed to produce technology, and how to dispose of or replace old technology. Again, even though these questions often apply to large-scale global technologies, citizens should ask the same questions of themselves regarding their use of smaller-scale technologies. Asking responsible questions

citizens.

Humans have

presence on the earth.

earth's physical enviro

awesome. But it is al

agriculture, manufact

world to live life to th

inequity in the distrib

continues to expand

great importance. F

fundamental factor

disease). Likewis

humanity's future.

seriously issues su

It could be argued

scientifically liter

aware of how tec

potential of emer

study of technolo

who implement

knowledge of tea

The liter

emergence of in

Stan (1994-95

of rationales fo

responsible questions and acting on the answers are qualities of technologically literate citizens.

Humans have shaped the world they live in since the beginning of human presence on the earth. Technology provides almost limitless opportunities to alter the earth's physical environment. In one sense, controlling that magnitude of power is awesome. But it is also an awesome responsibility. On the one hand, advances in agriculture, manufacturing, and energy production have allowed some people in the world to live life to the highest living standard. One glaring problem is the obvious inequity in the distribution of technology and its effects. As the human population continues to expand rapidly, the use and distribution of technology will continue to be of great importance. For example, the ability to increase agricultural productivity will be a fundamental factor in human survival (assuming the world's population continues to increase). Likewise, the wise use of finite resources will determine the direction of humanity's future. As shapers of the physical world, surely we must begin to take seriously issues such as deforestation, desertification, and overpopulation, among others. It could be argued that more than ever before, society needs to be stocked with scientifically literate citizens. In studying the real world around them, students should be aware of how technology has shaped the world. They should also be aware of the potential of emerging technologies. MEGOSE, the NSES, and SFAA all include the study of technology as a recommended part of the science curriculum. Thus, teachers who implement science curricula based on these documents would promote students' knowledge of technology and its role in students' real world.

Section C: Introduction to Instructional Technology

The literature on instructional technology is abundant, despite the relatively recent emergence of instructional technology in K-12 schools. Fulton (1993), Viau (1994), Itzkan (1994-95), Max (1994), David (1990), Cuban (1993) and others offer definitions and rationales for technological literacy, and its role in K-12 education. Because of the recent emergence of

in academe link the

the process of school

in K-12 schools is not

identify and study sit

at the center of curric

instructional technolo

its use in schools, des

analyze characteristics

Instructional Techno

The link betwe

to be scientifically lite

technology. Just as th

science teaching and l

technology across the

of school reform.

Novelli (1993

change in student to c

the statistics on the p

schools were well-ad

recent emergence of and rapid expansion of the forms of instructional technology, many in academe link the implementation of instructional technology across the disciplines to the process of school reform. In other words, widespread use of instructional technology in K-12 schools is not the traditional paradigm. Thus, it is useful for researchers to identify and study situations in which instructional technology has moved from the fringe to the center of curricular efforts. In this section, I explore the rationale for the use of instructional technology in schools, contrast views on the future of technology vis-a-vis its use in schools, describe exemplary instructional technology programs in schools, and analyze characteristics of exemplary technology-using teachers.

Instructional Technology: Its Rationale and Role in the Reform of Schooling

The link between scientific literacy and technology has been made in this study; to be scientifically literate one must understand and be able to apply knowledge about technology. Just as the authors of SFAA view their efforts as necessary to reform K-12 science teaching and learning, other scholars view the implementation of instructional technology across the spectrum of American schools as a necessary, if not vital, element of school reform.

Novelli (1993) described the increase in numbers of computers in schools and the change in student to computer ratio from 1983 to 1993 (see table below). In looking at the statistics on the proliferation of personal computers in schools, one would think that schools were well-advanced in implementing instructional technology:

Table 2 Dis

1983
% of scho
Student to co

In pre

1993 concl

schools has d

instructional

and the refor

misleading th

instructional

in our society

schools.

Whe

educators an

classroom te

been realize

replace print

s in the wa

technology?

living in a w

forever revol

people live th

coming in to

Then that

considered,

Table 2 Distribution of Computers in Schools

1983	1993
•57% of school districts have PC's •Student to computer ratio = 125/1	•92% of school districts have PC's •Student to computer ratio = 16/1

In presenting these statistics on the distribution of computers in schools, Novelli (1993) concluded that "things have changed" (p. 34)! While the numbers of computers in schools has drastically increased since 1983, the impact that computers and related instructional technology have made on curriculum, teaching and learning, administration, and the reform of schools in general is a matter of debate. The figures are also somewhat misleading due to issues of equal access to the computers and obsolescence of the instructional technology itself. Below I contrast different views on the role of technology in our society and the reform potential of instructional technology in America's K-12 schools.

When personal computers first appeared in K-12 schools, circa 1981, many educators and parents wondered aloud whether the technology would take the place of classroom teachers, thereby radically changing the teaching profession. That fear has not been realized. Similarly, some have wondered whether electronic media may someday replace print media. In his deliberations about technology, Max (1994) wondered if print is "on the way out" (p. 61). Will books be replaced by CD-ROM and other multimedia technology? Various gurus of current "cyberspace" suggest that Americans are currently living in a world that is changing so quickly electronically that people's lives are being forever revolutionized. The information superhighway will completely redefine the way people live their lives. If that is true, then what are the implications for teaching and learning in today's (and tomorrow's) schools? While some multimedia programmers predict that "the book will become the equivalent of the horse after the invention of the automobile," others argue that the information superhighway is already over-hyped and predict that technological problems such as built-in obsolescence, costs, and incompatibility will prevent the electronic revolution from reaching the heights that some predict (Max, 1994). Thus, the role of technology and how schools might be transformed by it are still in question.

Novelli (1993) and Bruder (1993) argued that instructional technology is not only a partner in the pursuit of scientific literacy but is spearheading the effort. Bruder (1993) argued that while the use of instructional technology in science education has been on the periphery and used by a "minority of teachers," the recent emphasis on the reform of K-12 science teaching has increased the appeal of integrating instructional technology into new science curricula. But will the reform of science and technology be a catalyst in integrating instructional technology or will it remain on the fringe of reform?

While current science education reformers argue the efficacy of instructional technology as a component of scientific literacy, Cuban (1993) is pessimistic about the degree to which instructional technology will become a factor in school reform. Cuban (1993) expressed his sentiments regarding computers' marginal impact on education over the past decade with the caption "Computers meet classroom; classroom wins" (p. 185). In his analysis of the effects of technology on classrooms and curricula, Cuban (1993) argued that other technologies, including film, radio, television, and video, have cycled their way into the mainstream of American education and none have significantly reformed curricula, teaching, or learning. Nevertheless, Cuban acknowledged that instructional technology seems to be here to stay and provides three scenarios that portray the role of instructional technology in American schools ten years from now. Following is a summary of those scenarios.

Scenario 1 - The Technophile's Scenario

In this scenario, all schools have become technologically rich environments in which instructional technology has significantly contributed to making teaching and learning far more productive than they are today. The vision of "electronic schools" has

been achieved largely by providing each school the necessary "critical mass" to make technology available to all students. This scenario could not be achieved, Cuban argued, by implementing pilot programs and increasing instructional technology little by little.

Scenario 2 - The Preservationist's Scenario

Preservationists see instructional technology primarily as a way to improve productivity, not necessarily as a means to reform values about teaching, learning, and school organization. In this scenario, schools will integrate more technology into classrooms, but rather than reform education, the new technology will merely reinforce the purposes and values of schools as they have existed for over one hundred years. However, as more instructional technology enters schools and classrooms, pockets of excellence will emerge, where real reform of mathematics, science, and technology will be achieved. Certain school districts, individual schools within districts, or even individual classrooms within schools, will be identified as places where instructional technology has contributed to fundamental school and curricular reform.

Scenario 3 - The Cautious Optimist's Scenario

Cautious optimists view instructional technology as "the future" but believe change will come slowly. Optimists firmly believe that instructional technology will reform our thinking about teaching and learning, but because of the organization of schools and the time needed to master technology's learning curve, the change will resemble "a turtle crawling to its pond."

I describe Cuban's view as somewhat pessimistic because he argued that the preservationist view is the most probable scenario in high schools and the cautious optimist view is the most probable in elementary schools. In other words, our schools will probably not integrate instructional technology effectively enough to effect the type of systemic reform of science and technology that current reformers are calling for.

What a

will instructio

instructional te

training do cla

their curricula

integrating ins

doing so can b

the change. T

al. 1990) foun

changed to ac

technology. T

stages. Clear

without suppo

will not lead t

Sheingold & I

teaching para

classrooms. F

successfully i

ACOT study's

comfortable a

instructional t

There

What is neede

curricular imp

strategies.

What are other views on the role of instructional technology in schools? How will instructional technology influence curricular reform? How might schools use instructional technology to induce fundamental changes in teaching and learning? What training do classroom teachers need to help them integrate instructional technology into their curricula? The literature indicates that teachers' fundamental beliefs about integrating instructional technology into their curricula and their teaching strategies for doing so can be changed, but teachers progress through clearly defined stages to achieve the change. The Apple Classrooms of Tomorrow (ACOT) research project (Dwyer, et al., 1990) found that teachers' beliefs about teaching and learning must gradually be changed to accommodate teaching practices congruent with the use of instructional technology. The study also found that these changes occur slowly, with clearly defined stages. Clearly, buying and supplying teachers with the latest in instructional technology without support, professional development, and an extended time frame for integration will not lead to significant increases in the use of instructional technology. Similarly, Sheingold & Hadley (1990) found that lack of time for teachers' accommodation of new teaching paradigms significantly impeded integration of instructional technology into classrooms. Herman et al. (1992), and Becker (1992), in studies on teachers who successfully integrated instructional technology across the curriculum, concurred with the ACOT study's findings that time for accommodation, extensive teacher support, and a comfortable and relaxed atmosphere are extremely important in teachers' long-term use of instructional technology in classrooms.

There are many classrooms equipped with dusty computers that rarely get used. What is needed is a fundamental change in how teachers view the technology and the curricular implications of integrating instructional technology into their teaching strategies.

App

Tab

Apple Classrooms of Tomorrow: The ACOT Study

Dwyer et al. (1990) ACOT study concluded there are five phases that teachers go through in progressing towards a "technology intensive classroom." Following is a summary of that process:

Table 3 Five Phases of Progression to Technology in Classrooms

Phase	Expectation	Support
Entry	•each classroom is installed with a critical mass of technology	•extensive planning time provided for teachers
Adoption	•established instructional strategies maintained, with word processing and other software introduced	•technical support provided. Teachers' confidence built
Adaption	•curriculum integration of technology with increased teacher confidence	•staff training in applications software and multimedia. Introduction to "technology friendly" pedagogy
Appropriation	•faculty experimentation with team teaching, interdisciplinary project-based instruction, group work	•support for shift to student-centered learning. Introduction to performance-based assessment
Invention	•implementation of integrated curriculum, integration of authentic assessment, real shift to project-based teaching	•teachers collaborate with each other, mentor other teachers, reflect and publish, telecommunicate experiences.

In one sense this study confirms Cuban's concerns and doubts about the ability of innovative instructional technology to change teachers' fundamental beliefs about teaching and learning. However, the study also confirms that when supplied with technology - rich classrooms and administrative support, teachers might progress from the entry phase of technology use through to appropriation and invention. Because the research cohort participated in the study over a period of four years, teachers had the luxury of developing a paradigm shift gradually, which is not always the case in educational reform efforts.

While the ACOT study described the phases teachers go through in their integration of instructional technology, it did not address how new technology itself impacts existing teaching practice. Itzkan (1994-95) referred to this process as **diffusion theory.** He used three trends in classroom computing to illustrate the role emerging technology plays in a school. According to diffusion theory, technological diffusion

occurs in three stages: substitution, transition, and transformation. Essentially, they are analogous to the phases of teacher change in the ACOT study and are illustrated in the table below:

Table 4 Diffusion Theory

	Personal Computers	**Networking**	**Global Classroom**
Substitution (new technology)	**•Computers as electronic paper**	**•Networks as automated messaging**	**•Students as "pen pals"**
Transition (new methodology)	**•Didactic versus constructivist paradigm**	**•Resource sharing**	**•International collaboration**
Transformation (new paradigm)	**•Computers as cognitive agents**	**•Networks as educational landscape**	**•Students as "global citizens"**

In the substitution phase, technology does not challenge existing paradigms, but replicates existing practice. In the transition phase, new teaching methodologies evolve which challenge existing paradigms. In the transformation phase, new methodologies have taken over from existing ones, transforming the classroom into a place where student and teacher roles are drastically different from the first phase of technology introduction. As the technology changes phases, the role of students, and by inference that of teachers, becomes increasingly complex and more demonstrative of a constructivist paradigm with instructional technology integrated into the curriculum.

Given the results of the ACOT study, why then don't school districts nationwide take a stronger position vis-a-vis integrating instructional technology into established curricula? One possibility is that as yet, there isn't good evidence about what students learn and understand in these transformed classrooms. Dede (1990) attributed educators' delays in utilizing emerging technologies to 'misconceptions' about instructional technology. For example, the "Misconception of Incrementalism" states that educators think that innovation in technology use can occur by slowly accruing more and more technology in each school building until finally, each student in the school has frequent and meaningful access. This philosophy of integrating technology into schools was also described in Cuban's scenario 3. Dede (1990) argued that this approach, combined with the other misconceptions, results in a superficial and ineffective approach to integrating instructional technology into school curricula.

In promoting instructional technology as a means of restructuring schools and curricula, David (1990), Collins (1990), and Sheingold (1990) were much more optimistic about technology's potential for contributing to the systemic reform of schools. David's (1990) argument is similar to that of SFAA and MEGOSE: that curriculum and instruction should be based on constructivist learning theory, de-emphasizing rote memorization and content coverage. In order best to match the technological society students live in with appropriate curriculum experiences in school, instructional technology must become not just available, but indispensable to the processes of teaching and learning. Like Dwyer et al. (1990), David (1990) concluded that teaching and learning must fundamentally change from the traditional paradigm to one that embraces the implementation of instructional technology across the curriculum.

Sheingold (1990) and Collins (1990) each argued that instructional technology should play a strong role in school reform, and that for reform to be maximized in a school district, a synergy must exist between active learning, the restructuring process, and technology. Specific recommendations for achieving this synergy closely parallel the transformation of teachers' beliefs and practices described in the ACOT study. This study of an exemplary technology-using elementary teacher contributes to the case literature on exemplary teaching, and could be used to develop new understanding about technology use for those teachers who have resisted transformative methodology. In the next section, I review literature that examines exemplary technology programs in schools and teachers who have embraced instructional technology in their teaching.

Instructional Technology in Schools and Teachers Who Utilize It

Needs assessments in many K-12 schools as well as colleges and universities indicate that while instructional technology is present, it is often used for little else than word processing and drill and practice (Grejda & Smith, 1994). While the reform rhetoric describes active learners utilizing technology to solve problems, it seems that scenario is played out largely as Cuban (1993) described in his three scenarios - pockets of technological excellence exist in schools, but are not widespread. However, given that educators favor disseminating curricular programs and "good ideas" by modeling them for others, one can theoretically study exemplary technology programs and the teachers who utilize instructional technology to its fullest potential. Thus, my study attempts to describe what such a "technology - rich" classroom might look like and why Ms. Brook integrates instructional technology into her science teaching. This section of the literature review examines how instructional technology is being used in elementary schools and profiles teachers who are instrumental in its integration.

Schools that utilize instructional technology to a high degree seem to view the technology as a support mechanism to existing curricula, rather than a separate goal or stand-alone program (Burkhouse, 1994; White, 1994; Jackson, et al., 1994). That is, instructional technology is integrated into the curriculum to help students solve real problems. The types of instructional technology (hardware and software) typically utilized in technology-rich elementary classrooms include: video camcorders, applications software, commercial software for instruction and administration, modems and telecommunications software, personal computers, input and output devices, hypermedia, multimedia stations, CD-ROM, videodiscs, interactive television, and projection systems (Crouch, et al., 1993; Novelli, 1993; Nemeth, 1993; Al-Jafari, 1993).

What do these technology-rich classrooms look like? There seems to be a continuum with adequate amounts of hardware and software on one end and the ACOT type of classroom on the other. The ACOT study equipped dozens of rural, urban, and suburba

scanner

software

students

classroo

[illegible]

the curr

implem

focus b

problem

more re

collabo

units a

[illegible]

suburban school elementary classrooms with Apple personal computers, printers, scanners, laserdisc and videotape players, modems, CD-ROM drives, and hundreds of software titles. In addition, each teacher had a personal computer on his/her desk and students were provided with computers at home. Others (probably more typical classrooms) are comparatively limited in hardware and software, but have the necessary "critical mass" that students and teachers need to effectively integrate the technology into the curriculum.

As teachers and students in the ACOT study progressed through the implementation steps of **entry, appropriation,** and finally to **invention**, the curricular focus became project-based, with students working in collaborative teams to solve problems. Teachers also noticed that as students' technology skills evolved, they took more responsibility for their own learning, and shifted from competitive work habits to collaborative ones (Dwyer et al., 1990). In describing the changes in students' work habits and attitudes, one teacher commented:

> We are finding that the students are coming in to use the computers during lunch and staying late to complete their HyperCard assignments for social studies on the countries they are researching. This degree of commitment and engagement is really unusual in a group of quite ordinary kids (Dwyer et al., 1990).

Novelli (1993) described enthusiastic teachers who are using telecommunications software such as National Geographic's Kids Network in science and social studies. In the "Saturn School of Tomorrow" project, the school is considered to be a "technology-rich" school (Bennett & King, 1991) in which students utilize computers, videodiscs, and other technology in solving problems. For example, 5th graders integrate instructional technology into mathematics and science curricula by writing computer programs that run cars that students build out of Lego parts. In the National Geographic KidsNet project, elementary students collect data on acid rain in their local regions, use the data to construct maps, and communicate their findings with students worldwide through the telecommunications component in KidsNet. The use of instructional technology in exemplary

feature of

engaged w

world prob

and other c

Other real-

contribute

students re

Bruder, 19

Exemplary

In H

teachers se

quantify "e

use of techn

standards to

and the tea

room enric

exemplary

determine w

the exempl

exemplary elementary classrooms seems to be virtually unlimited in scope, but a common feature of these classrooms is that they are student-centered, and students are actively engaged with the technology in working to solve real-world problems. In part, the real-world problems referred to here come from programs established by National Geographic and other organizations involved in science and technology education (Bruder, 1993). Other real-world problems emerge from classrooms in which teachers and students co-contribute to meaningful curricular units e.g., telecommunications projects in which students research local problems and share findings with students in other communities (Bruder, 1993; Dwyer et al., 1990; Bennett and King, 1991).

Exemplary Teachers Who Integrate Instructional Technology into Their Teaching

In his study on computer-using teachers, Becker (1994) examined why some teachers seem to be more effective in using instructional technology than others. To help quantify "effectiveness," Becker developed 21 standards with which to measure teachers' use of technology. Becker deemed those teachers who qualified on at least 11 of the 21 standards to be exemplary. In the broadest sense, exemplary computer-using teachers used the technology nearly every day, and in a way that supported the core curriculum, not in enrichment situations nor in mastery of "basic skills." Having identified a group of exemplary teachers, Becker then examined the work environments of those teachers to determine whether certain teaching environments supported computer use. Becker found that exemplary computer-using teachers work in environments that are likely to have:

•a social network of technology-using teachers in the school;
•technology used for learning and a wide variety of other goals such as publishing, business applications, etc.;
•a full-time computer coordinator with organized and on-going staff development;
•school leadership cognizant of the importance of equity in access to technology;
•smaller class sizes, more software, and a very favorable student-computer ratio.

While Becker's study did not determine which factors contribute to specific characteristics of exemplary teachers, it is useful in my analysis because it allows me to compare the study's findings to Ms. Brook's building-level working environment.

Becker's

exempl

the man

utilizes

and lear

environ

using te

Fulton

techno

compu

implem

the qu

The pe

of inst

1993

of the

in the

Becker's (1994) analysis is also helpful because I do categorize Ms. Brock as an exemplary technology-using teacher who does, in fact, utilize instructional technology in the manner suggested by Becker. My study focuses on the "story of how Ms. Brook utilizes instructional technology in teaching for scientific literacy," and what the teaching and learning in her classroom looks like. Thus, given that different teaching environments exist in schools (Becker, 1994), what might characterize the technology-using teachers themselves?

In her 1986 study on the availability and use of existing technologies in schools, Fulton (1993) emphasized the role of teachers in successfully implementing instructional technology into any curricula. While acknowledging the "excitement and electricity" that computers can bring to learning situations, Fulton noted that "computers are not self-implementing," and that like any tool, "they do the work to which they are applied, but the quality of the result depends upon the skill of the craftsperson who uses that tool." The central finding of Fulton's study, which examined different aspects of the utilization of instructional technology in schools was that the role of the teacher was key. As Fulton (1993) puts it, "No technology can overcome poor teaching" (p, 8). Given the importance of the classroom teacher in effectively implementing instructional technology in the curriculum, I next focus my review on teachers who are seen as "exemplary" or "leaders" in the use of instructional technology.

Solomon (1993), Ferris & Roberts,(1994), Dwyer, et al. (1990), and McCarthy (1993) describe teachers who utilize instructional technology in various curricular disciplines. This literature characterizes teachers who, for the most part, are relatively new to implementing technology into their teaching. One teacher emphasizes the role of technology in promoting inquiry in science teaching by describing the following scenario typifying how the technology is used:

> using historical data of worldwide temperatures, one group of students hypothesized that the polar ice caps should be shrinking. So far, the satellite images the students have analyzed don't support their premise. Whether they'll prove their theory or not, they're learning not only science

> and scientific method, but geography and social studies as well (Solomon, 1993).

On the utility of students using technology, this teacher stated, "the students get a much deeper understanding about science when using technology than from reading or listening to lectures about it." Although this teacher does not state how students' understanding was measured, I infer the teacher assumed more student understanding as a result of the depth to which students investigated topics utilizing instructional technology.

Another elementary teacher participating in the ACOT program utilizes technology with her students to conduct research, desktop publish class newsletters, and produce multimedia projects. This teacher emphasizes not only the importance of using instructional technology in teaching but also the broad support system present in the ACOT schools: "What's great is that we are all working together, so the real hub of change is teachers. It's stimulating" (Solomon, 1993, p. 17).

A third teacher suggests that neither curricular core courses nor technology courses should be taught in isolation from each other. In exploring the use of multimedia technology with students, the teacher feels that "my students are engaged in doing something real - using technology as a tool to get answers to problems they need to solve" (Solomon, 1993, p. 18). This teacher also relates a theme common in the literature on technology-using teachers: that students are excited by the teaching and learning and that teaching itself is more exciting and rewarding when using instructional technology. Again, the measurement of this learning might be an area for further research.

In presenting five case studies of teachers who are viewed as "technology leaders," Ferris and Roberts (1994) concluded that the teachers' success in implementing instructional technology into their teaching and in helping colleagues implement technology stemmed primarily from having adequate support. While in-school support was important, the teachers themselves viewed the relationship between instructional technology and the school's curriculum as equally important. "Make sure technology augments the curriculum rather than making technology an add-on" (Ferris and Roberts, 1994.

teacher

support

needed

Sec

applic

Ms Br

particu

teache

descri

review

scienc

such a

Teach

and w

Stud

Butt

1992

learn

Conte

Progr

teache

Each

1994). Other advice offered by exemplary technology-using teachers included teaching teachers to be comfortable with instructional technology, providing ongoing technical support to teachers, and educating parents and school boards about the level of support needed to sustain using instructional technology.

Section D: Teacher Knowledge and Expert Teaching, and Exemplary Science Teaching

Teacher education scholars, educational researchers, and teachers themselves espouse a variety of ideas on what constitutes expert teaching. In this study, I describe Ms. Brook as an exemplary science teacher who utilizes instructional technology in pursuing scientific literacy. One way in which scholars identify good or exemplary teachers is to contrast the novice with the expert teacher. Another way is to try to describe or quantify the knowledge exemplary teachers need or possess. In this section, I review different conceptions of "teacher "knowledge," "expert teaching," and "exemplary science teaching." In chapter five, I pursue a central question: "What makes Ms. Brook such an exemplary teacher?"

Teacher Knowledge and Expert Teaching

In the past two decades, many scholars have written about knowledge in teaching, and what teachers need to know about subject matter and the pedagogy of teaching (Shulman, 1986; 1987; Grossman, 1990; Feiman-Nemser & Featherstone, 1992; Buchmann, 1984; 1987; Ball & Wilson, 1990; and Cochran et al., 1993). Buchmann (1984) argues that content is a precondition for teaching - one must have something to teach and part of the meaning of teaching is an understanding of what is to be taught. Content knowledge helps the teacher to see a point from the learner's perspective and to recognize the internal logic of learners' questions and answers. Knowing content helps teachers recognize "teachable moments" that would otherwise go by (Buchmann, 1984).

Knowledge in teaching includes subject matter knowledge (content) but good teaching requires other types of knowledge as well. Wilson, Shulman, & Richert (1987) argue that expert teaching requires subject matter knowledge as well as a professional knowledge base. Components of the professional knowledge base include: 1) knowledge of subject matter; 2) pedagogical content knowledge; 3) knowledge of other content; 4) knowledge of curriculum; 5) knowledge of learners; 6) knowledge of educational aims; and 7) general pedagogical knowledge.

Duckworth (1987; 1988;) and Kohl (1984) argue that the pedagogy of teaching should focus on getting students to actively engage with the curriculum, and that children's ideas should be valued. Kohl (1984) describes a "teaching sensibility," knowing how to help students focus their energy and growth. Duckworth (1987; 1988) describes the pedagogy of teaching as giving students the occasion to have "wonderful ideas," and providing them the educational setting that suggests wonderful ideas.

Shulman (1986), in his review of research on teaching, refers to an absence of focus on subject matter as a "missing paradigm" in the research base. Shulman's historical analysis of the research on teaching suggests that the missing paradigm is a fairly recent phenomenon. In offering his perspective on teacher knowledge, Shulman (1986) raises several questions that are pertinent to my study of Ms. Brook and what makes her an expert teacher:

1. How does one make the transition from expert student to novice teacher?
2. How does the novice teacher, or a seasoned veteran, draw on expertise in the subject matter in the process of teaching?
3. How does the teacher prepare to teach something never previously learned? How does learning for teaching occur?
4. How do teachers take a piece of text and transform their understanding of it into instruction that their students can comprehend?

Questions three and four are particularly relevant to the study of Ms. Brook given that much of her teaching using instructional technology is "cutting edge." She described her own teaching as being "experimental, out there, figuring it out as we go along." Thus, Shulman's analysis of the specifics of pedagogy are crucial in understanding how Ms. Brook does what she does, and does it so well.

Shulman (1986) distinguishes three categories of teacher knowledge germane to preparation for teaching and the practice of teaching: content knowledge, pedagogical content knowledge, and curricular knowledge. In defining content knowledge, Shulman draws heavily on Schwab's substantive and syntactic structures of a discipline. In other words, content knowledge goes well beyond knowing the facts and concepts of a discipline to knowing the "rules" of a discipline, and how to determine the validity or invalidity of information within the discipline. It also refers to how much content knowledge a teacher has and how the knowledge is organized in the teacher's mind. Shulman (1986) argued that teachers must be capable of "defining for students the accepted truths in a domain" (p. 9). Teachers also must be capable of explaining relationships within the content, and what is worth knowing.

Pedagogical content knowledge is a subject matter knowledge for teaching. Shulman (1986) described pedagogical content knowledge as knowledge of the most regularly taught topics in one's subject area, the best way to represent those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations to use in teaching the topics. In other words, pedagogical content knowledge means how to best represent and formulate a subject so that it is comprehensible to others. In doing so, it is important to understand what makes the learning of a specific topic easy or difficult (Shulman, 1986). If students demonstrate misconceptions about a topic, the teacher needs knowledge of strategies to assist learners in reorganizing their thinking about subjects. In other words, pedagogical content knowledge involves knowing how to teach for understanding.

Finally, curricular knowledge means knowing about the "full range of programs designed for the teaching of a particular subject and topics at a given level, the variety of appropriate teaching strategies available, and knowing when to use such strategies and programs" (Shulman, 1986, p. 10). This involves knowing the importance of curriculum articulation: knowing what has been and will be taught in a subject area across a K-12 continuum. It also

given subject, and

This "lateral curri

relevant the conte

In his 198

Shulman reiterate

and also describe

five-year veteran

management of

expert teaching

teaching typical

Shulma

The first aspec

of comprehend

should know. H

subject and to

purposes for t

specialist sho

education, te

> ...the
> peda
> he or
> adap
> stude

The

transform w

their repre

variety of in

These proce

continuum. It also involves knowing about the range of curricular materials available in a given subject, and being familiar with students' curricular materials in other subjects. This "lateral curriculum knowledge" underlies the teacher's ability to relate or make relevant the content under study to issues being discussed in other subjects.

In his 1987 essay, Knowledge and teaching: Foundations of the new reform, Shulman reiterates his description of the categories of the knowledge base of teaching, and also describes a "portrait of expertise." In this portrait, Shulman showcases a twenty-five-year veteran teacher who has expertise in classroom management, but also on the management of ideas within classroom discourse. Shulman (1987) uses this portrayal of expert teaching to suggest that the hope in education reform is to make this type of teaching typical, rather than unusual.

Shulman (1987) also discussed teaching as a form of "pedagogical reasoning." The first aspect of pedagogical reasoning is comprehension. The teacher must understand or comprehend what is to be taught. This understanding should be deep, and the teacher should know how the subject being taught relates to different ideas within the same subject and to ideas in other subject areas. Comprehension also involves knowing the purposes for teaching a given topic or idea. Shulman (1987) argues that any subject specialist should have comprehension of their subject, even non-teachers. In Shulman's estimation, teachers are distinguished by:

> ...the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students. (p. 15)

The second aspect of pedagogical reasoning is transformation. This means to transform what one knows into a form that will be understood by students. This may mean representing the ideas by using models, analogies, and metaphors; selecting from a variety of instructional strategies; and adapting the ideas to the children being taught. These processes of transformation result in a lesson or unit plan, or an organized set of strategi

strategi

back on

events a

describe

analytic

experie

lack of

observ

specific

classro

above

not ma

their ap

centere

influen

argues

frustra

of Tea

enthu

teache

interv

Teache

teache

strategies to teach the material. Thus, the teacher must have knowledge of instructional strategies in order to implement the transformed material in the classroom.

The third aspect of pedagogical reasoning is reflection. This involves looking back on the teaching and learning process and rethinking, evaluating, or reenacting the events and emotions associated with the teaching and learning. This equates to what is described as "learning from experience." Reflection of this type is framed by some analytic criteria, which could include a consideration of the teaching and learning experience compared to the outcomes that were sought.

Lortie (1975) describes teaching as a private rather than a shared experience. The lack of a mediated entry into the profession, as well as a reliance on the apprenticeship of observation that many teachers experience may be reasons why novice teachers lack the specific knowledge of teaching described by Shulman and others. Also, teachers feel classroom experience is the key factor in learning to teach, thus experience is valued above most other forms of professional preparation. However, as Jackson (1986) points out, many novice and veteran teachers alike retain mimetic methodologies gained through their apprenticeship of observation. In contrast, progressive teachers foster student-centered classrooms, are transformative in their teaching, and use "soft-suasion" to help influence students' attitudes, values, and interests (Jackson, 1986). Lortie (1975) also argues that teachers' knowledge and purposes revolve largely around class events, and are frustrated by time taken away from teaching. Lortie (1975) referred to this as the Logic of Teacher Sentiments, and argued that in classrooms, there is a continuous, productive exchange between teacher and students. Of course, in figuring out what knowledge is needed to produce a "productive" exchange and indeed what "productive" means in this context is to figure out what good teaching is.

Lortie (1975) also suggested that teachers generally disregard the importance of their teacher education, and value instead their on-the-job experience. In her book about teacher knowledge and teacher education, Grossman (1990) argues for teachers' need for

pedagogical content knowledge, which teachers acquire to varying degrees through teacher education programs. She also provides evidence that novice teachers who don't acquire pedagogical content knowledge in their teacher education programs are very different from those who do.

Grossman describes how pedagogical content knowledge makes a difference by contrasting six novice teachers, three of whom entered teaching without teacher training and "learn on-the-job," and three who entered teaching having graduated from teacher training programs. In presenting the six case studies, Grossman argues that the three non-traditional novice teachers lacked what she called principled practice, the integration of theory and practice. She described the methods course taken by the three traditional novice teachers as being one in which "the conceptual frameworks were related to classroom practice, just as instructional strategies were analyzed in relation to the theoretical assumptions of the course. Theory and practice functioned as a double helix in which the two aspects played off each other, spiraling toward an integrated whole" (Grossman, 1990, p. 120).

In her text, Grossman describes four principles with implications for teacher education:

1. Students' active construction of knowledge through collaborative relationships;
2. The view that knowledge is tentative and flexible;
3. Knowledge should focus on helping novice teachers develop a sense of the overarching purposes for teaching rather than specific prescriptions for practice;
4. Theoretical principles that underlie teaching practices.

Thus, Grossman argues that knowledge is actively constructed, and is flexible and tentative, in direct contrast to the notions held by mimetic teachers (Grossman, 1990; Jackson, 1986). Finally, Grossman substantially supports Shulman's view of knowledge by arguing that disciplinary knowledge or subject matter alone does not provide teachers with the pedagogical understanding necessary for teaching a wide range of students (Grossman, 1990).

While Shulman describes fairly specifically what teachers need to know in order to teach effectively, other scholars wrestle with the tensions that exist in trying to define their subject areas both in terms of content and as a way of thinking and behaving within that discipline (Kennedy, 1989). Anderson's (1989) analysis of knowledge in science teaching argues that descriptions of "good teaching" are often simple characterizations, embedded with catch phrases such as "student-centered, inquiry, wait time" and so on. He provides a vignette of an exemplary science teacher with the caveat that the teacher skills and subject matter knowledge demonstrated by the teacher are the result of years of hard work on the part of the teacher. Thus, from a policy standpoint, it is naive to believe that good teaching can be replicated by most classroom teachers even after their participation in professional development workshops. Anderson (1989) describes good teaching as being very complex and part of a *pattern of practice* that includes extensive knowledge of the pedagogy described by Shulman.

Ball (1989) describes the type of mathematics knowledge teachers need to know in order to teach mathematics for understanding. She includes in this analysis knowledge of the content of mathematics, the nature and discourse of mathematics, mathematics in culture and society, and pedagogical reasoning in mathematics (Ball, 1989). This vision of teacher knowledge in mathematics is very similar to Anderson's view of teacher knowledge in science education and to the teaching standards developed by the National Research Council. In Ball's view, teaching mathematics for understanding involves the necessity for teachers to be able to "weave together" all the different aspects of mathematical knowledge listed above. Like Anderson, Ball described this as a very complex process.

Philips and Uprichard (1989) wrote that mathematics is unique among the sciences and supplement Ball's analysis by describing mathematics as a way of thinking, a study of related ideas and patterns, a language, an art, and a tool. Mathematics is a discipline students must experience in order for conceptual understanding to occur

(Philips & Uprichard, 1989). In their paper, Philips and Uprichard describe what mathematics should be taught in elementary school and how elementary teachers should teach mathematics. Essentially, they advocate teaching for understanding a direct teacher/student interaction as opposed to the common paradigms of lecture-and-listen, and distribute-and-collect (worksheets). Thus, teacher knowledge must encompass knowledge of teaching for meaning and understanding and the concepts taught must be meaningful and appropriate to students' level of cognitive development (Philips & Uprichard, 1989).

Wilson (1989) and Banks (1989) discuss two types of knowledge that history and social studies teachers need: (a) subject matter knowledge and (b) subject matter specific pedagogical knowledge. Wilson (1989) argues the importance of teaching students both the subject matter of the course and how to think critically about themselves, their values, the world around them, and their place in the world. Wilson's analysis contributes to this study because she argues for what beginning teachers need to know about teaching history, while many other scholars reviewed here (except for Grossman) focus on exemplary teaching by veteran teachers. While describing at length the subject matter and pedagogical knowledge needed by beginning teachers, she closes her argument with the warning that many beginning teachers do not, in fact, have that type of knowledge. Furthermore, taking more required courses in the content areas is no guarantee that teachers will develop the type of pedagogical reasoning and subject matter knowledge required to teach history effectively (Wilson, 1989). Thus, Wilson's analysis helps me think about the focus of chapter seven in this study: "What makes Ms. Brook such a good teacher?"

Sternberg and Horvath (1995) propose a prototype view of expert teaching that focuses on how experts differ from novices, and propose that teaching expertise "be viewed as a category that is structured by the similarity of expert teachers to one another rather than by a set of necessary and sufficient features" (p. 9). By incorporating standards

every exp

inexperie

In

from nov

their subj

effectively

The secon

planning.

Sternberg

novices.

classroom

together,

compared

Be

novice or

studying t

performan

which nov

Of

results in

them:

Th
de
tea
his
of

An

evaluate a

standards into this view of expert teaching, Sternberg and Horvath recognize that not every experienced teacher is an expert. Conversely, this view also allows that relatively inexperienced teachers may meet many of the standards of exemplary teaching.

In their model, Sternberg and Horvath identify three ways in which experts differ from novices. The first category is knowledge. Experts have a better understanding of their subject matter, and the principles to be taught than do novices. Experts also more effectively bring this knowledge to bear on the problems or issues within their domains. The second category characterizing the expert teacher is efficiency. In the areas of planning, teaching, and assessing students, experts "do more in less time than do novices" (Sternberg & Horvath, 1995). Finally, expert teachers demonstrate more insight than do novices. Expert teachers are more able to anticipate students' needs, predict problematic classroom situations, and arrive at novel and appropriate solutions to problems. Taken together, these three aspects help define what the expert teacher might be like as compared to a novice teacher.

Berliner (1986) argued for the need to study expert teachers, and compare them to novice or ordinary teachers. His review of studies on expert teaching revealed that studying the performance of experts is useful in instructing novice teachers. Experts' performance provides "a temporary pedagogical theory, a temporary scaffolding from which novices may learn to be more expertt" (Berliner, 1986, p. 6).

Of particular importance to the significance of my study is Berliner's argument that it is important to study expert teachers because we can learn from them. As Berliner puts it:

> They can, more than most teachers, provide us with the cases - the richly detailed descriptions of instructional events - that should form a part of teacher education programs. As Shulman (1986) so eloquently argued in his 1985 AERA presidential address, beginning teachers need such cases of practice to develop their full understanding of pedagogy. (p. 6)

Another reason to study expert teachers is that often, they are not particularly articulate about their high degree of expertise. This is partly due to the automation of procedures by experts. In other words, teaching routines are hardly noticeable to experts - they just do things expertly without thinking about why or how. Berliner (1988) expands on this point by describing expert teachers this way:

> Experts do things that usually work, and thus when things are proceeding without a hitch, experts are not solving problems or making decisions in the usual sense of those terms. They "go with the flow," as they say in California. When anomalies occur, when things do not work out as planned or something atypical is noted, deliberate analytic processes are used in the situation. But when things are going smoothly, experts rarely appear to be reflective about their performance. (p. 6)

Novices do not possess that ability. Thus, in teaching novices, it would be helpful to know how expert teachers perform routine procedures and solve problems when the need arises.

Berliner (1986) described several problems related to studying expert teachers, foremost among them is how to determine who is or is not an expert, and based on what criteria. In Berliner's view, expert teachers must possess two domains of knowledge: subject matter knowledge, and knowledge of organization and management of classrooms. Having established those criteria, Berliner described nine characteristics of expert teachers. Those characteristics are listed below:

1) experts apply their domain-specific knowledge to make sense of the classroom they are viewing (p. 10);

2) experts categorize problems to be solved at some kind of higher level, whereas novices classify problems to be solved by the surface characteristics given in the problem (p. 10);

3) experts have extraordinarily fast and accurate pattern recognition capabilities (p. 11);

4) experts take longer than novices to examine a problem, to build a problem representation, or to think through first strategies (p. 11);

5) experts are sensitive to the task demands and the "social structure" of the job situation (p. 11);

6) experts have been shown to be "opportunistic planners." They are quick to change tracks (p. 11);

7) experts show self-regulatory or meta-cognitive capabilities that are not present in less mature or experienced learners (p. 11);

8) expertise is developed only over long periods of time, say hundreds, perhaps thousands

of hou

9 expert
(p. 12

In sum, E

character

teachers

Exempla

S

Nationa

each tea

standard

then sum

Overvie

A

compon

for exem

envision

active le

students

ability t

exempla

curricula

of their

T

NRC, 1

setting

Planning

of hours of learning experience (p. 12);

9) expert's unique knowledge shows up in relation to the goal structure of a problem (p. 12).

In sum, Berliner provided a rationale for studying expert teachers, described nine characteristics of expert teachers, and argued that one of the best ways to teach novice teachers is to study experts and use those cases as teaching tools.

Exemplary Science Teaching

Standards for exemplary science teaching are described in chapter three of the National Science Education Standards (NRC, 1996). In chapter five of this study, I list each teaching standard and provide evidence showing that Ms. Brook exemplifies each standard. In this section, I describe an overview of the science teaching standards, and then summarize each specific standard.

Overview of the Science Teaching Standards

Although classroom teachers are central to the education process, they are but one component of systemic reform of science, mathematics, and technology. The standards for exemplary science teaching described by the National Research Council (1996) envision a classroom environment where "teachers and students can work together as active learners" (p. 28). To facilitate this process, science teachers must be well-grounded in theory, have practical knowledge in their subject area, and demonstrate the ability to teach science utilizing a variety of methodologies (NRC, 1996). In doing so, exemplary teachers plan and implement an inquiry-based science program which includes curricula that "meets the interests, knowledge, understanding, abilities, and experiences of their students" (NRC, 1996, p. 30).

The exemplary teacher subscribes to the philosophy that "teaching is not telling" (NRC, 1996; Jackson, 1986). Rather, exemplary teachers of science guide and facilitate learning, orchestrate scientific discourse among students, challenge students to accept responsibility for their own learning, and model the skills of scientific inquiry (NRC, 1996). Ev

new ideas

AAAS, 19

assessmen

teaching.

instruction

way, even

students.

Fi

inquiry, p

environm

the tools,

active lea

Teaching

In

term goa

to meet t

T

abilities,

order to

Carnegie

teaching

effective

Science

Professi

1996). Exemplary teachers also promote habits of mind such as curiosity, openness to new ideas, and developing a skepticism about data and the scientific process (NRC, 1996; AAAS, 1990). Knowledge of teaching and learning is closely linked with new visions of assessment of students. Exemplary teachers utilize assessment data to guide their teaching. That is to say that assessment tasks are not merely "afterthoughts" to instructional planning, but are built into the instructional design (NRC, 1996). In this way, exemplary teachers have the knowledge to best meet the needs of all of their students.

Finally, exemplary science teachers create learning environments that promote inquiry, problem-solving, and collaboration. Such an environment is a safe working environment, visually stimulating, functionally designed to support inquiry, replete with the tools, equipment, and technology resources needed by students, and encourages the active learning of science (NRC, 1996).

Teaching Standard A

In planning an inquiry-based science program, teachers develop long and short-term goals. These goals, along with school district, state, and national goals are adapted to meet the interests and needs of their students.

Teachers select science content, adapt, and design curricula to match the interests, abilities, and experiences of their students. In doing so, curriculum remains flexible in order to respond to student inquiries and experiences, and current events that arise. Curricula is also planned, and amended where necessary based on assessment and teaching strategies that promote students' understanding. Planning is a cornerstone of effective science teaching and is done individually and collectively. In the National Science Education Standards' view, group and grade level planning "is a vehicle for professional support and growth" (NRC, 1996, p. 32).

Teaching

Th

stages of

NRC, 19

actively

ideas, cha

students

including

scientific

In

opportun

students

engaging

values, a

F

and learn

Teaching Standard B

This standard focuses on the teaching role in facilitating scientific inquiry. "At all stages of inquiry, teachers guide, focus, challenge, and encourage student learning" (NRC, 1996, p. 33). In fulfilling this role, teachers help focus and support inquiries by actively interacting with students; orchestrate discourse among students about scientific ideas; challenge students to accept responsibility for their own learning; encourage all students to participate in science learning; and model the skills of scientific inquiry including curiosity, openness to new ideas, and developing a skepticism about the scientific process (NRC, 1996).

In order to teach for scientific inquiry, teachers need to create challenging opportunities for students, and promote inquiry by asking questions, and assisting students in making sense of their experiences. Also, teachers need to model inquiry by engaging in it. Enthusiasm for and interest in scientific inquiry instills positive ideas, values, and attitudes towards science in students.

Teaching Standard C

Planning and teaching strategies are driven by ongoing assessment of the teaching and learning in the classroom. Multiple assessments are used to gauge students' understanding, and this data helps guide science teaching. Assessment strategies are formal and informal, and use of assessment data extends far beyond the purpose of informing parents about student progress. "Skilled teachers guide students to understand the purposes for their own learning and to formulate self-assessment strategies (NRC, 1996, p. 42)." Thus, students should be actively-involved in the assessment process, working with the teacher to develop skills in reflecting on their own work.

Teaching Standard D

This standard focuses on teachers designing and managing a learning environment that provides students adequate space, time, and resources necessary to pursue scientific inquiry. Stu

the classroo

technology

and use res

the classroo

Teaching S

Ex

reflect the

a significa

Thus, stu

Teachers

discourse

group lea

1996, p.

Teachin

S

science

needed

develop

would

these s

change

inquiry. Students need time to engage in extended investigations. As much as possible, the classroom environment should support students' inquiry by having the tools and technology for inquiry readily available. Effective teachers also help students identify and use resources outside the school. The learning environment should extend beyond the classroom and utilize community and school resources.

Teaching Standard E

Exemplary science teachers develop and nurture communities of learners that reflect the processes and rigor of scientific inquiry. Teachers encourage students to have a significant voice in making decisions regarding the content and context of their work. Thus, students should have a voice in determining the type of inquiry they engage in. Teachers promote and nurture collaboration among students and facilitate scientific discourse among students. In doing so, "effective teachers design many activities for group learning, not simply as an exercise but as collaboration essential to inquiry" (NRC, 1996, p. 50).

Teaching Standard F

Science teachers actively participate in planning and developing the school science program. This involves planning and organizing the time, space, and resources needed to promote scientific inquiry, and participation in professional growth and development programs to enhance their skills in teaching science.

The National Science Education Standards recognize that most science teachers would not currently meet the teaching standards as described and that the development of these skills requires systemic change in science education. The table below outlines the change in emphases in science teaching that underlie the Teaching Standards.

Tab

Table 5 Changing Emphases in Science Teaching

Changing Emphases	
Less Emphasis on	More Emphasis On
Treating all students alike and responding to the group as a whole;	Understanding and responding to individual student's interests, strengths, experiences, and needs;
Rigidly following curriculum	Selecting and adapting curriculum;
Focusing on student acquisition of information;	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes.
Presenting scientific knowledge through lecture, text, and demonstration;	Guiding students in active and extended scientific inquiry;
Asking for recitation of acquired knowledge;	Providing opportunities for scientific discussion and debate among students;
Testing students for factual information at the end of the unit or chapter;	Continuously assessing student understanding;
Maintaining responsibility and authority	Sharing responsibility for learning with students;
Supporting competition;	Supporting a classroom community with cooperation, shared responsibility, and respect;
Working alone	Working with other teachers to enhance the science program. (NRC, 1996; p. 52)

These changes in emphases suggest that exemplary science teachers would focus more on facilitating learning by actively engaging students in scientific inquiry, would pay more attention to the needs of individual students through more effective assessment and teaching strategies, and would promote a collaborative rather than a competitive atmosphere in the classroom.

Raizen and Michelson (1994) described the qualities of an effective science teacher based on recommendations of the National Board for Professional Teaching Standards. Those qualities are as follows:

•Teachers are committed to students and their learning (p. 31);

•Teachers know the subjects they teach and how to teach those subjects to students (p. 31);

•Teachers are responsible for managing and monitoring student learning (p. 31);

•Teachers think systematically about their practice and learn from experience (p. 31);

•Teachers are members of learning communities (p. 31);

•Teachers consider the social, ethical, and civic implications of their actions both inside and outside the classroom (p. 31).

Taking thes

specifically

describing

teachers ha

created, org

and Michel

which is ve

> Fu
> sci
> pos
> an
> sci
> of

Razen an

points sim

example,

scientific

and pedag

To

case stud

and Frase

advocate

and Yage

studies in

advocate

science te

> W
> sc
> ei
> an
> sc
> (p

Taking these general recommendations, Raizen and Michelson then elaborated on each, specifically relating these recommendations to elementary science teaching. In describing exemplary elementary science teachers, Raizen and Michelson argued that teachers have a rich understanding of science and understand how scientific knowledge is created, organized, linked to other disciplines, and applied to real-world settings (Raizen and Michelson, 1994). Raizen and Michelson also described a view of scientific inquiry which is very similar to that described in the National Science Education Standards:

> Further, accomplished elementary teachers know and can use the skills of scientific reasoning that they are expected to foster in their students: posing questions, designing investigations, gathering and analyzing data, and drawing conclusions. They know, value, and demonstrate such scientific "habits of mind" as a desire for knowledge, skepticism, tolerance of ambiguity, and honesty (p. 37) (In Bybee et al., 1989).

Raizen and Michelson's (1994) description of exemplary science teachers contains many points similar to those expressed in the National Science Education Standards. For example, systematic assessment of students' learning, learning communities supporting scientific inquiry, the professional development of teachers, knowledge of subject matter and pedagogical content knowledge, are all qualities of an exemplary science teacher.

Tobin and Fraser (1987) and eleven members of their research team developed case studies of twenty exemplary science teachers. As a rationale for the study, Tobin and Fraser cited the work of Berliner (1986) and Shulman (1986), both of whom advocated the need for case studies of expert teachers. Also cited was the work of Penick and Yager at the University of Iowa. Penick and Yager (1983), concluding that past case studies in science education primarily highlighted the plight of science education, advocated developing case studies of exemplary science teachers in order to improve science teaching:

> What we wanted were case studies of **excellence** (emphasis in original) in science education that would guide and provide support for innovative efforts. By heeding such case studies, we thought that much of the trial and error associated with educational innovation could be eliminated and school programs could begin building on what was known to work. (p. 621)

Writing in th

rationale for

The
chem
both
teac
prog
teac
Thus
pote
natio

Thus, the w

case studies

Tobi

mathematics

through twel

science teac

primary sch

Lac

in develop

specific a

instructio

education

of the

p
a
so
an
their

Writing in the foreword of Tobin and Fraser (1987), James Gallagher suggested further rationale for developing cases of exemplary science teachers:

> The case studies in this report on exemplary teachers in biology, chemistry, physics, general science, primary science and mathematics at both primary and secondary levels provide data about teaching which teacher educators can use in both preparatory and continuing education programs. In addition, this work provides a model for research on teaching which others can implement in their own teaching contexts. Thus, this report not only provides foundational data but also it has the potential for stimulating similar studies of exemplary teaching in other nations and in differing teaching contexts. (p. xi)

Thus, the work of Tobin and Fraser (1987) provides a strong rationale for the need for case studies of exemplary science teachers.

Tobin and Fraser's (1987) comprehensive study of exemplary science and mathematics teachers focused on teachers in grades one, three, four, five, six, and eight through twelve. Particularly relevant to my study is the chapter on exemplary primary science teaching, in which Lacy (In Tobin and Fraser, 1987) studied two exemplary primary school teachers. I conclude this section by describing Lacy's findings.

Lacy (1987) studied a grade 3/4 composite class, and a grade 5/6 composite class. In developing the case, data was collected on the students and classroom in general, and specific aspects of science teaching such as: teacher training and preparation for instruction, science equipment and materials, structure of lessons, and science program evaluation. An interesting finding of this study was the exemplary teachers' description of when they felt they were most effective:

> Barbara explained that she considered herself to be most effective in teaching science when she explained the purpose of the lesson to the children, provided them with sufficient appropriate materials and then permitted them the time and freedom to direct their own experiments to investigate the problem upon which the lesson was focused. Grant perceived that some of his more effective strategies included: explaining the importance of activities to children at the beginning of lessons; provision of a number of examples to illustrate or clarify important points; assisting pupils either individually or in groups; pretending not to know something and allowing sufficient opportunities for children to explain; and carrying out his own experiment while children were conducting theirs. (p. 100)

These teachers seem to put emphasis on having clear goals and objectives for the lesson, and promoting processes of scientific inquiry. Their own perceptions match some of the NSES' recommendations for exemplary science teaching, particularly the emphasis on scientific inquiry.

In his findings, Lacy described seventeen characteristics that might indicate exemplary science teaching. From the students' perspective, exemplary science teachers were seen to be friendly, supportive, and purposeful. Exemplary teachers were confident in their science teaching ability, had sufficient background knowledge to teach primary science, and utilized an activity-based, hands-on approach to teaching science.

Exemplary teachers ensured students access to sufficient and appropriate materials and resources, allowed sufficient time to pursue scientific inquiry, and made sure students understood the objectives or purposes of science lessons. The time allocated to science teaching was flexible, with teachers frequently reorganizing their schedules in order to spend more time than usual on science teaching. Teachers were familiar with a variety of commercially produced science resources, maintained an aesthetically pleasing learning environment in the classroom, and were active participants themselves in science lessons (Lacy, 1987).

Lacy described aspects of exemplary science teaching that are consistent with other scholars and policy makers (NRC, 1996; MEGOSE, 1991; Raizen and Michelson, 1994; Tobin and Fraser, 1987). As part of the same study, Tobin (1987) compared exemplary high school science and mathematics teachers with a non-exemplary comparison group, and the differences between them were marked. Exemplary teachers viewed teaching in terms of facilitating student learning, established a productive learning environment, and had friendly, supportive, and positive interactions with students. Each exemplary teacher believed that students created their own knowledge through active engagement in science tasks. In facilitating students' learning, exemplary teachers utilize

expect

accep

proble

conte

exper

from

data

Liter

utilized a wide range of teaching strategies, and in all cases, teachers held very high expectations of students. Behavior problems during lessons were minimal.

In contrast, the comparison teachers were primarily engaged in maintaining acceptable levels of student engagement with the material, and minimizing behavior problems. Tobin concluded that the comparison teachers' content and pedagogical content knowledge were effectively nullified by the management problems they experienced in the classroom.

I conclude this chapter with a discussion of the relevant points that have emerged from this literature review, and I present the interpretive framework used for organizing data analysis in chapters four and five.

Literature Review Findings

In chapter two, I reviewed literature on current conceptions of scientific literacy, technology and instructional technology, teacher knowledge and expert teaching, and exemplary science teaching. Each of these points relate back to the research questions, and are examined in detail in chapters four and five. Below I summarize the important points that emerged from the literature review.

Scientific literacy is the goal of K-12 school science programs. But what is scientific literacy? What should scientifically literate students be able to do? This literature review demonstrated the complexity of these questions. Although the term scientific literacy dates back to the 1970's, I chose to focus on current conceptions of scientific literacy to inform this study.

Hazen and Trefil (1990) and Flaste (1991) argued that citizens' most basic need vis-a-vis scientific literacy is to be able to understand public issues. While Hazen and Trefil (1991) argued for the mastery of core science concepts, Flaste (1991) argued that Americans could become scientifically literate by reading distilled versions of science issues and concepts in the news media. These two views of scientific literacy emanate from sources outside the science education community. While informing the study, they did not gi

literacy.

Th

promotes

traditiona

controve

Th

NEGOS

Each of

classroo

Nationa

a scienc

Standar

systemi

the Na

literacy

play in

teache

would

literac

Scien

Ins

199

Sta

Phys

Re

did not give specific recommendations for how schools should teach for scientific literacy.

The STS view of science teaching challenges the traditional paradigm. It promotes the organization of science concepts around social issues rather than the traditional science disciplines. For this reason, the STS movement has remained controversial since its inception.

The two conceptions of scientific literacy that most informed this study were MEGOSE (MDE, 1991) and the National Science Education Standards (NRC, 1996). Each of these reform initiatives focus on what K-12 teachers and students can do in the classroom to promote scientific literacy. MEGOSE is very similar in philosophy to the National Science Education Standards, and is used extensively in Michigan's schools as a science curricular blueprint. Like MEGOSE, the National Science Education Standards focus on scientific literacy, but also examine several components of the systemic reform of science education. What emerged from my review of MEGOSE and the National Science Education Standards was the complexity of the concept of scientific literacy and how to achieve it. Each document focused on what role teachers should play in effecting scientific literacy. Because this study is a case of an exemplary science teacher, it follows that both MEGOSE and the National Science Education Standards would be more appropriate in influencing the study than other views of scientific literacy.

This study examined Ms. Brook's use of instructional technology in teaching for scientific literacy. Therefore, it was important for the study to distinguish between the terms "technology" and "instructional technology." Science for All Americans (AAAS, 1990), Benchmarks for Science Literacy (1993), and the National Science Education Standards (NRC, 1996) all describe technology as something humans use to modify their physical environment. However, the National Science Education Standards also describe instructional technology as tools teachers and students use to conduct scientific inquiry.

review a

S

knowled

study of

what co

literatu

teachin

Anders

subjec

(1996

et al. (

necess

argue

under

for sp

For e

teach

Stand

Frase

with

Thu

exem

inquiry. The differentiation of these two terms is an important point in the literature review and is critical in order to understand the type of case developed in this study.

Section D of the literature review examined current research on teacher knowledge, expert teaching, and exemplary science teaching. In order to develop a case study of an exemplary elementary science teacher, one must have an understanding of what constitutes exemplary teaching and how this study is situated in the current literature. This literature review established some of the characteristics of exemplary teaching. For example, Shulman (1986; 1987), Buchmann (1984), Kennedy (1989), Anderson (1989), Ball (1989) and Wilson (1989) argued the importance of disciplinary subject matter knowledge in effective teaching. Shulman (1986; 1987), Grossman (1990), Duckworth (1987; 1988), Kohl (1984), Wilson (1989), Banks (1989) and Wilson et al. (1987) argued that subject specific pedagogical content knowledge was also a necessary component of effective teaching. All these scholars, in one way or another, argued of the complexity of teaching, and the need for teachers to possess a deep understanding of teaching and learning. The literature review also provided the rationale for studying exemplary teachers and what is currently known about exemplary practice. For example, Berliner (1986) and Shulman (1986) argued that knowledge of expert teaching was useful in instructing novice teachers.

The National Science Education Standards (NRC, 1996) describe specific standards that promote excellence in science teaching. Other scholars such as Tobin and Fraser (1987; 1989) and Raizen and Michelson (1994) informed this study through their writing about exemplary science teachers and standards for exemplary science teaching. Thus, this literature review provided a broad framework for examining Ms. Brook as an exemplary teacher, one who promoted scientific literacy through her teaching.

Introdu

T

I chose

experie

method

were d

attemp

techno

provid

study

instru

differ

imple

curr

value

litera

colle

Sett

CHAPTER 3

METHODOLOGY

Introduction

This study is a case study, by definition one that utilized qualitative methodology. I chose qualitative methodology because I was interested in understanding Ms. Brook's experience as a science teacher in a natural setting - her classroom. Qualitative methodology also provided the best way to answer the study's research questions, which were designed to be answered in part from rich narrative emerging from the data. Thus, I attempted to "tell the story" of what science teaching for scientific literacy looks like in a technology-rich elementary classroom. In telling the story, the "insider perspective" provided by Ms. Brook, and the participant observer perspective were central to the study. The study describes Ms. Brook's knowledge, values, and beliefs regarding science, instructional technology, and scientific literacy. It also describes and analyzes three different types of technology episodes, and the teaching and learning associated with their implementation. The study also analyzes technology episodes, interdisciplinary curricular activities associated with one electronic fieldtrip, and Ms. Brook's knowledge, values, and beliefs regarding science, instructional technology, and teaching for scientific literacy. In this chapter, I described the setting in which the study was done, data collection and analysis, and moving from data to claims or conclusions.

Setting - Jefferson Township

This study took place in a heterogeneous fourth grade class in Jefferson, a suburban school district located in the upper Midwest. Jefferson itself is not actually a town, but a postal community. It is located near a large university and a greater metropolitan area. The school district is located in parts of three counties, although the bulk of students are drawn from one county.

T

rapid gr

expand

commer

adjacent

the grea

Table 6

Within
Jefferso
Jefferso
Jefferso
Within
Metrop
Auto M
State G
Univer
Jefferso
Hospit

Approx

medica

indicat

fact, ag

townsh

agricu

family

tertiary

of citiza

The primary township in the school district, Jefferson Township, has experienced rapid growth since the late 1970's and, while maintaining a rural flavor, continues to expand rapidly. Most people in the community are employed in the light industrial, commercial, governmental, and educational centers in the greater metropolitan area adjacent to the township. The major employers within the Jefferson school district and the greater metropolitan area include:

Table 6 Employment information for Jefferson Public Schools & Area

EMPLOYER	PRODUCT OR SERVICE	NUMBER OF EMPLOYEES
(Within school district area)		
Jefferson Public Schools	Education	300
Jefferson Township	Government	135
Jefferson Food Store	Retail Grocery	125
(Within Greater Metropolitan area)		
Auto Manufacturing	Automotive Industry	20,200
State Government	Governmental Services	15,600
University	Education	11,000
Jefferson, Inc.	Retail	4,100
Hospital	Medical	3,500

Approximately 7,000 other jobs are situated in various educational, manufacturing, medical, and postal facilities in the greater metropolitan area. County demographics also indicate a small and decreasing number of citizens engaged in commercial agriculture. In fact, agricultural enterprises appear in a "patchwork" distribution throughout the township. Most of the farms appear to be family farms as the infrastructure typical of agribusiness firms is absent. Farmland is interspersed with relatively new multiple-family housing units, apartment complexes, strip malls, restaurants, and various types of tertiary industry.

Demographically, the Jefferson community is fairly young, with the average age of citizens being 32.9 years. Economically and financially, the community is robust with only 4.5% of families living below the poverty level and the median family income equaling $45,141. Of the 4,765 housing units in Jefferson, 31.4% were built during the decade of 1980-1990. Today, Jefferson is witnessing a rapid reduction of agricultural and wooded property combined with a rapid expansion of commercial and multiple family housing units including apartments and condominiums. Although the number of rental units is increasing, currently only 10% of residents rent, while approximately 87% of residents own their own home. I was unable to determine the housing situation for the remaining three percent of the population. Given that 4.5% of families live below the poverty line, it is possible that a small percentage might be homeless, itinerant, or live with friends or family, thus would not show up in demographic statistics as either home owners or renters.

While the racial makeup of the school district could be described as heterogeneous, it's students are primarily Caucasian. Following is a breakdown of the Jefferson school district according to race:

Race	**Number of Residents**
White	9,796
Black	192
Am. Indian, Eskimo, Aleut	53
Asian, Pacific Islander	129
Hispanic Origin	184
Other Races	60

Thus, while Jefferson school district displays some racial diversity, it is predominantly white.

Jefferson Elementary School

Jefferson Elementary school enrolls approximately 400 students in grades two through five in a single building. The administrative staff includes a principal, three secretaries, a part-time school counselor, and a part-time school psychologist. Support faculty consists of two resource room teachers, four para-professionals, one coordinator of the At Risk and Title I programs, a media specialist, and "specials" teachers in art, music. a

through

awards

structu

the rap

office.

focus

and co

the sc

comp

each

techn

of tra

focu

incl

edu

scie

an

pla

spa

con

o

org

ea

music, and physical education. There are 17 regular classroom teachers in grades two through five.

The school itself is a newly-remodeled building that has received numerous awards for its design. Three years ago, renovations were completed on the original structure, roughly tripling the size of the school. The renovation was undertaken due to the rapid expansion of student population in Jefferson township. Aside from ample office, classroom, and storage space, the school also contains "special" facilities. The focus point of the school is the newly-renovated library which houses video, television, and computer facilities in a carpeted, comfortable setting. The media specialist serves as the school's librarian, and also teaches each classroom on a weekly basis. A modest computer lab containing 10 Macintosh computers, 3 printers, and storage space is used each period of the day by classroom teachers and students. While the district has a technology specialist, there is no computer coordinator in the school.

The school is built around a 50' x 50' courtyard which is landscaped with a variety of trees, shrubs, bushes, flower beds, and lawn. Located just off the library, it also is a focal point of the school. The old gymnasium serves as the school's multi-purpose lunchroom with stage, and the new gymnasium is a teaching station for physical education and after school sports. The school contains an art room, new music room, a science room, and a "Kid's Connection" room which is a classroom dedicated to before and after school care for students.

The exterior of the building is relatively nondescript, with the usual assortment of playing fields and playground equipment. Exterior facilities include paved playground space, a basketball court, soccer field, and a large parking lot for school personnel and community members. One distinguishing feature is a low-lying natural wetland area that is used as a teaching station by faculty. This area is also being developed with the cooperation of the Department of Natural Resources into a permanent wildlife viewing area complete with boardwalk. Currently, one of the fifth grade teachers, Mr. Santo, is co-wr

will b

Selec

ter f

loca

to a v

edu

dif

plan

co-writing a Grade 2-5 ecology curriculum with university ecologists. The curriculum will be implemented by Jefferson school faculty during the next school year.

Selection of Participants for the Study

This study initially focused on two teachers and their students: Ms. Brook and her fourth grade class, and Mr. Santo and his fifth grade class. The two classrooms are located adjacent to each other on the same side of the hallway. Both classrooms are close to a variety of support facilities including the computer lab, counseling and special education office, cafeteria, and after school care room.

The decision to narrow the study to one teacher instead of two was particularly difficult. Ms. Brook and Mr. Santo showed an extraordinary level of collaboration in the planning and implementation of their science curricula. They also collaborated on grant writing activities which have proven extremely successful. Much of the science and instructional technology equipment present in the two classrooms resulted from successful grants written by Ms. Brook and Mr. Santo. Sharing and swapping of classrooms, frequent physical presence in each other's classroom, and concurrent implementation of technology projects made it easy for the researcher to be initially involved as a participant observer in both classrooms. I was also readily accepted in both classrooms by students.

However, I quickly realized that I faced one of the classic dilemmas of the qualitative researcher - time. To complete my study on schedule would require me to observe in only one classroom. Because Mr. Santo had a teaching intern in his classroom and was thus preoccupied with that role, I decided to focus my study on Ms. Brook and her students. Removing myself from Mr. Santo's room was a gradual process which was mutually agreed upon. One of the most rewarding aspects of my stay in the school, however, was in maintaining a close professional relationship with Mr. Santo, even after my departure from his classroom. I frequently sought his counsel on science and technology matters, which enabled us to develop a very meaningful professional relationship throughout the school year.

Five students in Ms. Brook's class were chosen for inclusion in this study. Their role was to provide student perspectives on their use of instructional technology in pursuing scientific literacy in their classroom. The group was chosen with the assistance of Ms. Brook and consisted of two males and three females. Because of the relative homogeneity of the student population in the classroom, race was not a factor in selecting the students. When asked for suggestions on selecting the student participants, Ms. Brook suggested students who were "verbal," that is, students who could easily discuss teaching and learning practice in the classroom. Ms. Brook provided an initial list of names that were also broken down by academic ability with high, medium, and low ability represented. I then spent considerable time observing in the classroom before the five students were chosen. After considering Ms. Brook's suggestions and observing in the classroom for several weeks, I chose five students for participation based on the following criteria:

- a high to low range of academic ability;
- a visible interest in using instructional technology in the classroom;
- an almost equal ratio of males to females.

I also interviewed each of the five students to ensure that they would be willing to spend time with me outside the classroom for interviewing purposes. Finally, one of the female students was selected because while she did not readily volunteer information in the classroom, and did not appear to be as involved with technology as some of the other students, I had observed her in the computer lab and classroom helping students with the available instructional technology. In other words, she seemed to be not only interested in using the instructional technology, but freely assisted her classmates when they needed help with the technology in the classroom or computer lab.

The group of five students chosen for participation in the study was not a "focus" group as such. They were not seated together, nor did they work together regularly as a group.

depend

togethe

perman

would

activi

intervi

clear t

perspe

focuse

metho

throug

learne

input

Ms. B

appro

strug

delive

discu

Wher

the cl

those

group. Because Ms. Brook moved students around in the classroom frequently, depending on the type of learning activity, these students would occasionally work together, but usually for only a morning or afternoon. Jackie and Susan were permanently seated across from each other as were Beth and Vern. Nonetheless, rarely would all five students be working together on a project.

For the most part, I observed the students in their use of technology in classroom activities and interviewed them individually and/or in pairs. Data regarding student interviews are documented in this chapter. However, as the study evolved, it became clear to me that time and resources would not permit the inclusion of students' perspectives in the final report. As data analysis progressed, the study increasingly focused on Ms. Brook, and her role as an exemplary science teacher. Thus, I made the methodological decision to eliminate students' perspectives from the study. However, through hours of classroom interaction with students, and through interviewing them, I learned a great deal about the science teaching and learning in the classroom, and their input and perspectives helped me clarify the focus of the study.

Ms. Brook's Classroom

The classroom is an average-sized elementary classroom measuring approximately 25' by 30'. It contains a hot and cold water faucet with sink area, 20 storage lockers for student use, blackboards covering two walls, bulletin boards, storage shelves, and a carpeted floor. It physically resembles many elementary classrooms. Its distinguishing feature is that the entire west wall faces into the school's interior courtyard.

The wall space in Ms. Brook's classroom is utilized to the maximum with a variety of classroom materials that are both colorful and instructive. The north wall of the classroom is entirely covered with a blackboard and bulletin boards. The bulletin boards typically display a variety of materials including:

•student-produced work such as writing samples and artwork;
•informational posters;
•maps.

While

the sa

freque

curren

writin

topics

Lami

anima

maps

techn

elem

two c

comp

is ce

prod

is lo

with

add

stud

but a

clas

in

sto

co

rt

While the types of materials covering the walls and bulletin boards remained essentially the same throughout the school year, Ms. Brook rotated the contents of the space frequently, replacing older samples of student work and posters with material from current units. For example, when students were studying the Kobe, Japan earthquake, writing samples from that topic were displayed on the wall. As the class pursued other topics, the writing samples and artwork changed to reflect the current topic of study. Laminated posters that have been displayed include Flamingowatch, various types of animal posters, tesselations, wetlands, etc. Maps displayed on the wall include world maps and Michigan maps of various scales demonstrating different geographical data.

The classroom is also equipped with a moderate amount of instructional technology, although it is well-equipped compared to most classrooms in the building and elementary classrooms in general. The classroom is wired for cable television, and has two cable-ready televisions with VCR's mounted on portable trolleys. There are two computer stations which are used almost daily by Ms. Brook and her students. Station 1 is centered on a movable trolley and contains an IBM computer with hard drive and printer. This station is used primarily for word processing and graphics work. Station 2 is located on the opposite wall and is centered on a desk area. This station is equipped with a Macintosh computer with printer, and a modem for telecommunications. In addition, Ms. Brook has frequently brought in her personal IBM laptop computer for students to use for Internet searches.

Although the school has a modest computer lab, other teachers' classrooms were not as well equipped with instructional technology as Ms. Brook's and Ms. Santo's classrooms. For example, no other classroom contained televisions permanently mounted on the wall; teachers could "check-out" televisions and video equipment from a central storage closet. Similarly, no other classroom was "wired" for cable television, or contained a telephone line for use with modems. Mostly, classrooms were equipped with relatively dated computer equipment such as Apple IIe, IBM 286, or compatibles. I

observed
hardwar
to my o
commer
was un
though
all set t
suppor
Do yo
staff r
the sy
unuse

instr
than
there
instr

observed that much of the computer equipment was either rarely used or contained hardware components that were incompatible. For example, the tutoring room adjacent to my office contained an Apple IIe, one external disk drive, and a printer, all housed on a commercially built computer table on wheels. Having only one disk drive, the system was unable to run the word processing software in the school's software collection. Even though an Apple Imagewriter printer was part of the configuration, the dip switches were all set to work with another hardware configuration. Having noticed that the tutors and support personnel never seemed to use the computer in their room, I asked them one day, "Do you ever use this Apple computer for doing your work and preparation?" One of the staff replied "We don't know how to make it work." With a little work, I was able to get the system up and running only to find the printer was defective. Thus, the system sat unused for the remainder of my tenure at Jefferson.

In many respects, Jefferson was typical of many public schools in that the instructional technology housed in classrooms was either defective or obsolete. Other than the requirement that teachers take their classes to the computer lab once per week, there was no technology plan for the school or requirement that teachers integrate instructional technology into their teaching strategies. The district technology coordinator made regular visits to the school to initiate conversations about long-range technology plans, or to assist teachers who needed help, but there was no official on-site technology coordinator. The "unofficial" technology coordinator was Mr. Santo. His classroom was located adjacent to the school's computer lab, and Mr. Santo was regarded as a technology leader by the administration and faculty. Thus, Mr. Santo spent much time working with colleagues in an ad hoc manner in the computer lab.

Clearly, Jefferson could not be described as a technology-rich school. Even the "new" computer lab was relatively obsolete. Given the limited resources most teachers had to work with, it is not surprising that most chose not to become involved with the

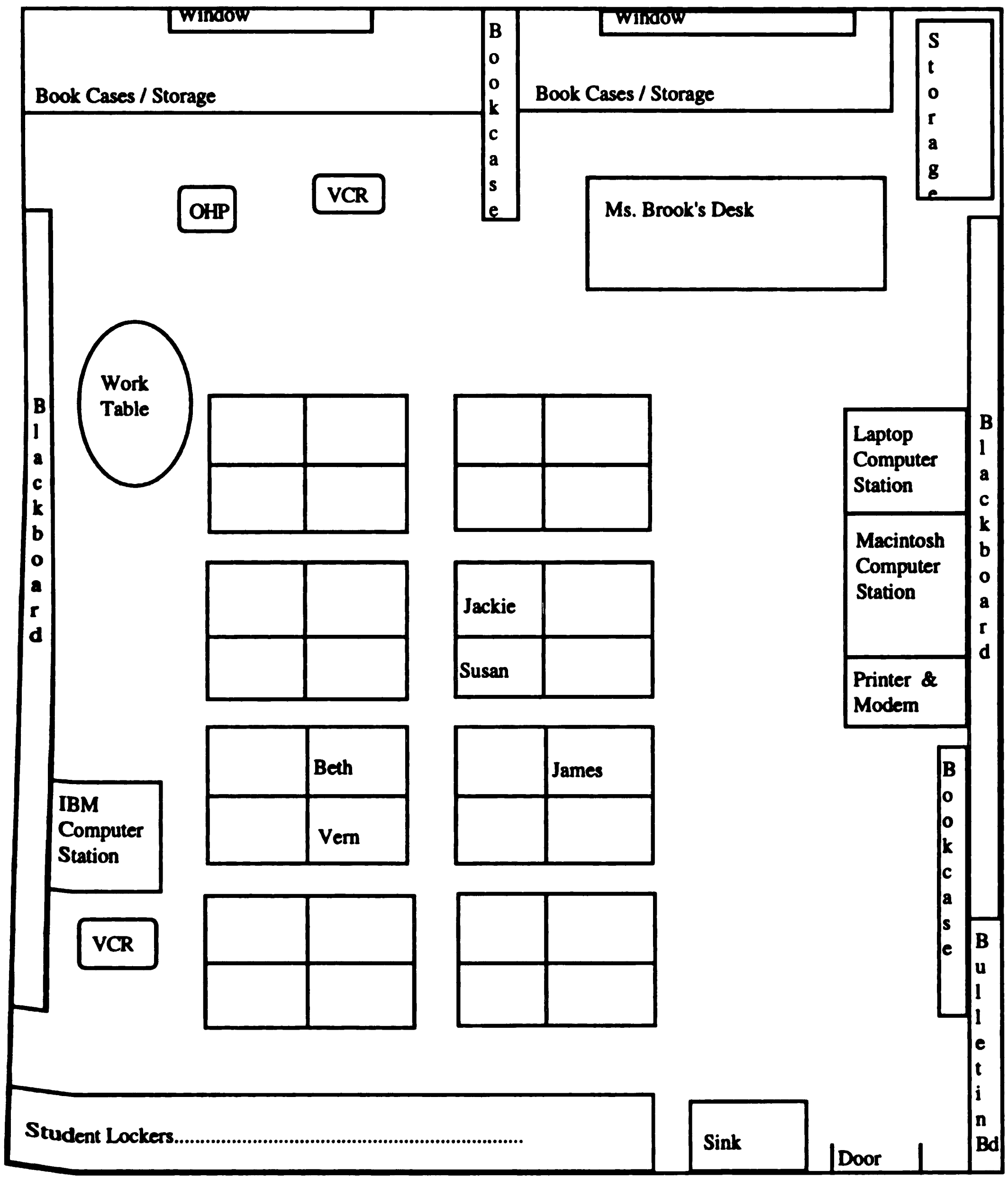


Figure 1 Ms. Brook's Classroom

type of

Santo.

at Jeffe

technol

That p

storage

movem

for stu

stand

dimen

Ratio

along

indu

proc

top

rese

dat

nat

sys

type of technology-rich curricula developed and implemented by Ms. Brook and Mr. Santo. Cuban (1993) accurately described the climate for technology use as I observed it at Jefferson: lacking the "critical mass" of technology needed to make instructional technology available to all students, a "pocket of excellence" emerged within the school. That pocket of excellence was created by Ms. Brook and Mr. Santo. Even though the storage areas in the classroom were "cluttered," the room itself allowed for easy movement throughout. Students frequently used the floor surface as well as their desks for studying and working collaboratively. On occasion, Ms. Brook also had students stand up to work with partners so, in essence, the classroom was used three-dimensionally by students.

Rationale for Data Collection

Erickson (1986) described the process of data collection as lying somewhere along the continuum from "radically inductive" to "as deliberate as possible." On the inductive end of the continuum, the researcher views the collection of data as a magical process, one in which the researcher holds no pre-conceptions about methods or even the topic of study. In contrast, a more deliberate approach to research design involves the researcher seeking answers to specific research questions, and methodically collecting data to provide evidence for claims or conclusions. My study is more deliberate in nature, with a specific focus, a set of research questions to frame the study, and systematic data collection and analysis procedures.

As a participant observer, I collected data in Ms. Brook's classroom over a period of five months. This type of site-based research required that I conduct extensive, observational fieldwork (Erickson, 1986; Bogdan & Biklen, 1992). Erickson (1986) specifically described fieldwork as involving:

•intensive, long-term participation in a field setting;
•careful collection of fieldnotes and other evidence;
•analytic reflection using narrative vignettes and direct quotes.

Interpr

the res

a descr

how p

everyo

metho

and o

imple

other

scien

prim

of th

very

Interpretive methods based on intensive fieldwork are most appropriately employed when the researcher wants to answer questions about social actions in a particular setting; when a description of the setting (e.g. a classroom) is desired; and when one wishes to describe how participants in a particular setting interact with one another in the conduct of their everyday lives is of interest (Erickson, 1986). Firestone (1993) described qualitative methods as being useful for "understanding the perspectives of teachers, students, parents and others; for clarifying the processes that take place in classrooms, during program implementation and in other areas; and for generating hypotheses for testing through other methods." Because I wanted to understand how Ms. Brook's conception of scientific literacy was enacted in her classroom, I chose participant observation as my primary data collection strategy.

When conducting fieldwork, much time is usually spent in gaining the confidence of the subjects, allowing them to confide in the researcher and behave normally in their daily routines (Bogdan & Biklen, 1992). I feel I achieved this status in the classroom very quickly. Students were used to seeing me around the school due to the fact that I also supervised teaching interns in three of the school's classrooms. In planning the study, I also had occasion to visit Ms. Brook's classroom informally to talk with her about my role, etc. Although I was not then collecting data, students became familiar with my presence in the classroom.

Once data collection began, I observed in the classroom almost daily. Ms. Brook asked me to assume a role that would be as active as possible without compromising my data collection ability. She wanted the students to view me as more than a researcher who took notes in the classroom and was a passive observer. She wanted students to view me as "someone who really cares about what is happening in this room." Thus, in the first week of data collection, I presented a slide show to the class which focused on Japan. At the time, students were studying the terrible events surrounding the earthquake that occurred in Kobe, Japan. In this way, Ms. Brook assisted in my involvement with and acceptance by students. A further description of my role as participant observer follows in this chapter.

One might reasonably ask, "What are data in a qualitative study?" Bogdan and Biklen (1992) define data as: "The rough materials researchers collect from the world they are studying; they are the particulars that form the basis of analysis." In this context, data might include a wide variety of materials including fieldnotes, interview transcripts, various curricular documents, photographs, diaries, journals, and so on. Data should be gathered and stored carefully, and contain the evidence needed to confirm or disconfirm claims (Bogdan & Biklen, 1992).

Data Collection Particular to This Study

To understand how Ms. Brook utilized instructional technology in pursuing scientific literacy, I observed in her classroom almost daily over a period of five months. While Ms. Brook was very open and accommodating throughout this process, data collection was difficult at times. Ms. Brook is a veteran teacher who has clear goals both short and long-term. However, daily lesson plans frequently depended on what was happening in the world's current events. Much science and social studies teaching in this classroom revolved around current events, especially if the events happened to correlate to science topics in the district's curriculum guide. In terms of data collection, this was a "double-edged sword." Because of the prominence of current events in the curricula, and because Ms. Brook followed a flexible schedule for when she taught science, I quickly realized that I would have to check with Ms. Brook daily regarding not only what she would be doing vis-a-vis science teaching, but whether I needed to visit the classroom at all. Consequently, there were some days where I missed out on data collection because science activities occurred "on the spur of the moment." On the other hand, there were many other days when Ms. Brook would see me in the hallway and say "you have to come around this afternoon. We're going to be doing this neat activity you have to see!" In most cases, these unexpected lessons included students' use of the Internet in exploring

Table 7 Dissertation Interview Schedule - Ms. Brook and Students

Name	Topic/Date	Topic/Date	Topic/Date	Topic/Date	Topic/Date
Ms. Brook	1/11 Scientific Literacy (SL)	2/17 Scientific Literacy & Technology	3/8 Kobe Teacher Bio Technology	3/23 Virtual-China Iditarod (Internet)	4/12 Scientific Literacy Curriculum Teaching
Ms. Brook	4/13 Scientific Literacy	5/2 Flamingo-watch	5/11 Flamingo-watch Misc.	6/15 Flamingo-watch	
Vern	2/28 Kobe Technology Science	3/16 Flamingo-watch Technology Science	3/21 Flamingo-watch Technology Science		
James		3/16 Flamingo-watch Technology Science	3/21 Flamingo-watch Technology Science		
Jackie	2/28 Kobe Technology Science			3/24 Flamingo-watch Virtual-China Internet	
Susan	2/28 Kobe Technology Science		3/23 Flamingo-watch Technology Science	3/24 Flamingo-watch Virtual-China Internet	
Beth	5/3 Technology Flamingo-watch				

current events topics. Thus, while I missed out on some data collection days, I was unexpectedly rewarded with rich opportunities on others. While this wasn't an easy situation in which to collect data, I tried to remain flexible, respecting Ms. Brook's role as the teacher. To establish baseline data on how Ms. Brook perceived scientific literacy, I conducted two interviews with her in the first month of the study. This data allowed me to compare her conceptions of scientific literacy with the ways in which she utilized instructional technology in pursuit of scientific literacy. The interviews, combined with classroom observations and document analysis, also enabled me to compare Ms. Brook's conceptions of scientific literacy with the dimensions of scientific literacy used in the study's coding schema for analysis. Finally, the interviews contributed to the development of a case study of Ms. Brook as an exemplary science teacher.

Participant Observation

As stated, data collection also involved the researcher as a participant observer in the classroom. In this role, the researcher observed students and Ms. Brook interacting in the classroom during science lessons. The amount of active engagement by the researcher was negotiated with Ms. Brook and included occasionally working with small groups of students (co-teaching), or helping Ms. Brook when asked. Much time was spent taking fieldnotes, which comprise a large part of the data corpus. However, I was sensitive to the need to observe and participate in a non-intrusive way. Although the term 'participant observer' is frequently used in describing the role of the researcher in qualitative methodology, its meaning may be interpreted differently. Gold (1969) described a participant observer continuum that ranges from "complete participant" on one end to "complete observer" on the other. Following is a graphical representation of Gold's model and more specific analysis of my role as participant as observer in this study.

Table 8 Participant Observation Continuum (Gold, 1969)

Complete Participant	Participant-as-Observer	Observer-as-Participant	Complete Observer
Heavy emphasis on participation.. Researcher plays the role of those being studied. Commonly referred to as "going native."	Researcher spends more time participating with rather than observing informants. This role does include both formal (scheduled interviews) and informal (attending meetings) observations.	Involves mainly formal observations based on one-visit interviews. Researchers in this role risk developing a superficial understanding of their informants	Researcher has a complete lack of social interaction with informants. This role is almost never used as the dominant one. This is almost the exact opposite of "going Native."

Table 9 Participant Observation Table

Informants	1/11	1/12	1/16	1/18	1/19	1/23	1/24	1/25	1/26	1/27	1/30	2/1	2/2	2/3	2/8
Vern											PO	PO	PO	PO	
Jackie											PO	PO	PO	PO	
Susan											PO	PO	PO	PO	
James											PO	PO	PO	PO	
Beth											PO	PO	PO	PO	
Ms. Brook	1A	O	O	O	O	O,TI	O	O	O	O,TI	O	O	O	O	O
Small Groups							O1		O1		PO1	PO1	PO1	PO1	
Whole Class		O	O	O	O			O1	O	O		O	O	O	O

Informants	2/9	2/10	2/13	2/14	2/15	2/16	2/17	2/24	2/28	3/1	3/2	3/6	3/7	3/8	3/16
Vern	PO		PO			PO			1B			PO			
Jackie	PO					PO			2A			PO			PO
Susan	PO					PO			2A			PO			PO
James			PO			PO						PO			
Beth						PO						PO			
Ms. Brook	O	O,TI	O,TI	O	O	O	1A	O,TI	O	O	O,TI	O	O	1AO	O
Small Groups						PO1		PO1	PO1		PO1	PO1			
Whole Class	O	O	O	O	O	O		O	O	O	O		O	O	O

Informants	3/17	3/20	3/21	3/23	3/24	3/27	3/28	4/11	4/12	4/13	4/14	4/17	4/18	4/28	5/1
Vern			2A												
Jackie			2A		2A										
Susan				1B	2A		1B								
James															
Beth															
Ms. Brook	O	O	O	1AO	O	PO	O	O	1A	O1A	O	O	O	O	O
Small Groups				O	PO	PO				PO					PO
Whole Class	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

<u>Key</u>

1A	Interview Ms. Brook	PO	Participatory observation[3]
1B	Interview one student	O1	Non-participatory class observation[2]
2A	Interview two or more students together	PO1	Participatory observation[4]
O	Non-participatory class observation[1]	TI	Teacher interaction[5]

Superscript Key

1. Observing Ms. Brook and the whole class but not participating in any way
2. Observing small groups but not participating in any way
3. Observing the whole class but also worked with students individually
4. Observing the whole class but also worked with students in small groups
5. Observation of Ms. Brook interacting with other teachers in planning, etc.

The above represents a record of my role as a participant observer. In these different roles, I observed in whole class and small group situations. I also classify my participant observation as either a participant or non-participant. Following is a table that illustrates the total number of occurences of each type of participant observation.

Table 10 Participant Observation Types by Number and Percentage of Occurences

Type of Observation	Number	Percentage
O	78	58.6
O1	4	3.0
PO	42	31.5
PO1	9	6.7

As the table above indicates, the most common form of observation involved the "PO" and the "O" categories (90.1%): observing the whole class but working with students individually and observing the whole class including Ms. Brook but in a non-participatory way. In most cases, the PO type of observation was conducted by circulating throughout the room during whole-class instruction and observing students working, or quietly asking them questions while they worked. Every class visitation involved direct or indirect observation of Ms. Brook regardless of whether I participated during observations. Also, each class visitation involved informal discussions with Ms. Brook.

The Participant Observation Table also indicates that on certain days, my data collection focused on interviewing either Ms. Brook or students. For example, on

February 17, I interviewed Ms. Brook and that was the extent of data collection for that day. On February 28, I interviewed Vern individually, Jackie and Susan together, and also made classroom observations. Most of my active participation in data collection sessions involved the PO and PO1 categories in which I worked either with individual students or with small groups of students. Typically, Ms. Brook would ask me to work with a small group of students at a computer station while she instructed the rest of the class. After eight to ten minutes, the group would return to their seats and another small group would rotate to the computer station. In other situations involving my active participation, Ms. Brook would ask me to participate in either a demonstration, laboratory experiment, or activity. For example, on May 1, Ms. Brook was conducting a lesson on "the scientific method," in preparation for the school science fair. In order to demonstrate the concept of variables, she asked me to assist her in a short activity in which she took the pulse of one student while I took the pulse of another student. After taking the students' pulse, she facilitated a discussion about the methods we used, how to graph the results, etc. Thus, my role as a participant observer varied, involving both active and passive observation techniques. Even though I participated actively on several occasions, I believe my role did not change or influence what actually happened in lessons. Ms. Brook's students were used to frequent visitors to their classroom, and I was merely another person available to assist students.

Data were maintained in two ways. First, fieldnotes were dated and entered into a word processing program in my computer. The original fieldnotes were filed in a folder and left in my home office. The hard copies of computer files of fieldnotes were kept in chronological order in my portable storage box. Thus, the portable notes were always available for analysis. Each set of fieldnotes also contained a title or heading, indicating the topic for the day. This method facilitated keeping the data in chronological order. However, some data were collected out of order. For example, interview transcripts may have been produced subsequent to a special lesson or event related to the interview. In this case, data were grouped together in a folder according to the activity or teaching episode. Some documents that are extensive and required considerable analysis were kept in a 3-ring binder. Fieldnotes, transcripts and other types of data pertinent to such large topics were kept in a folder and stored with the 3-ring binders. In terms of the electronic management of data, I kept all information on my computer's hard drive. In addition, each different part of the dissertation, from the proposal to final dissertation chapters was backed-up on floppy disks. One set of floppies was kept in a holder next to the computer, and a master floppy was kept in another location, for security's sake.

This study developed a single case (as opposed to multiple cases) which examined an elementary teacher's conception of scientific literacy, her view of the role instructional technology played in pursuing scientific literacy, and biographical information about the motivations of an elementary teacher in her use of instructional technology. Yin (1993) refers to this type of analysis as a descriptive case study. Yin (1989) describes an exemplary case study as one that reflects a strong, positive example of the phenomenon of interest. Because of its primary focus on an exemplary technology-using teacher, this study could be also described as an "exemplary" case study (Yin, 1989). One benefit of the study might be to illustrate how Ms. Brook, an exemplary teacher, utilizes instructional technology on a regular basis. Another benefit of the study might be to illustrate a case of a teacher who exemplifies many of the characteristics of good science teaching as described in the National Science Education National Science Education Standards and other literature.

The variety of data collected in the study has been described above. Because Ms. Brook's use of instructional technology was the focus of the study, and because Ms. Brook was project-oriented in her curricular planning, large amounts of data on "technology episodes" were collected. For example, Ms. Brook was very involved in technology projects called "Electronic Fieldtrips," in which students became actively involved in interactive cable television fieldtrips to exotic locations. The Flamingowatch fieldtrip involved much research on the topic prior to the trip, in which various types of electronic information retrieval techniques were used. The fieldtrip itself involved viewing three one-hour interactive videos over a three-day period. The project concluded with real-time telecommunications among students worldwide on the issues and science content revealed in the fieldtrip.

In chapter four, I present the data and provide analysis, description, and interpretation. At the conclusion of each section, I present the findings. To help organize the analysis and reporting of the data, I developed an interpretive framework. Following is the study's interpretive framework:

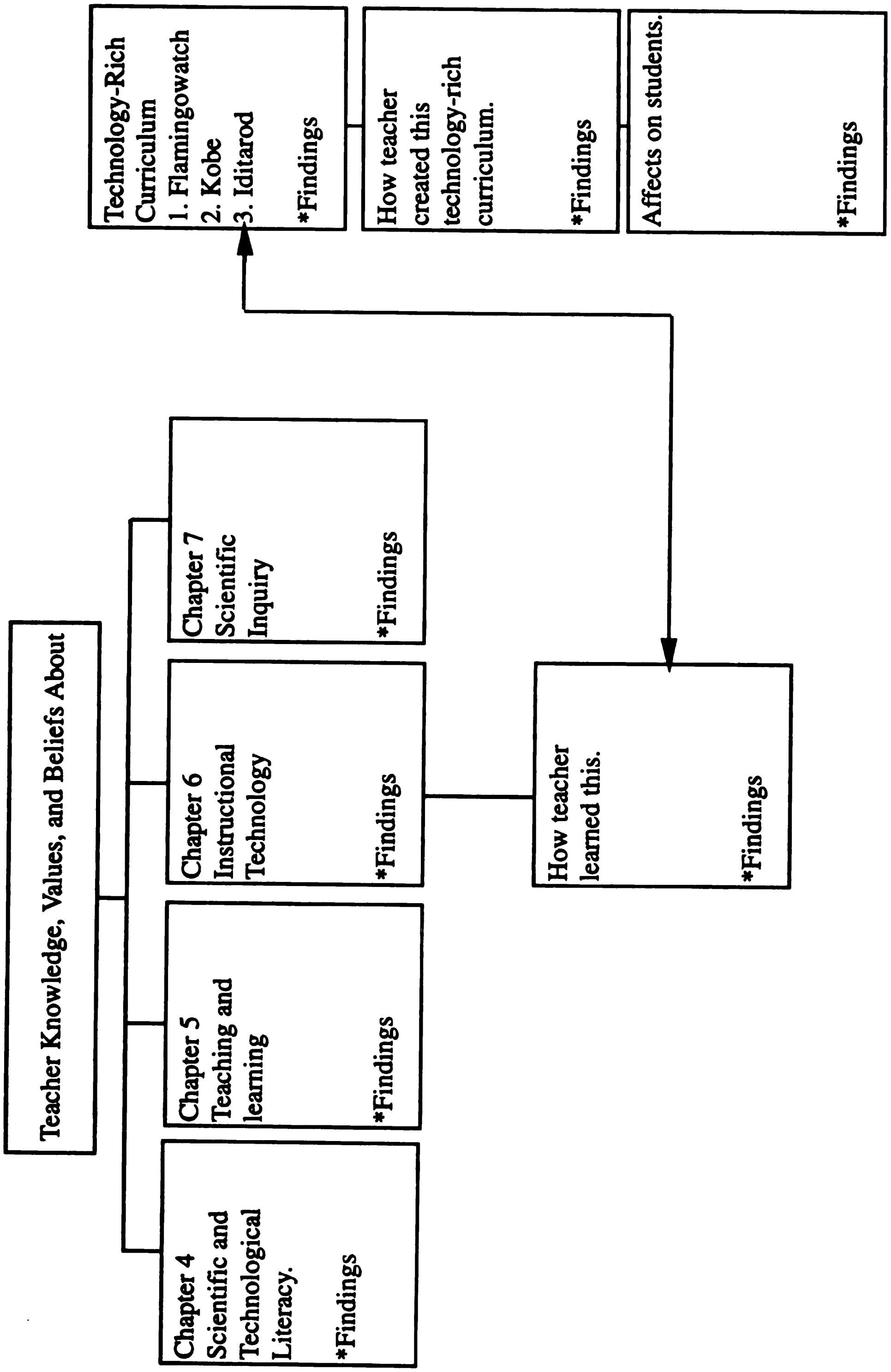
Data Analysis

In qualitative studies, data analysis is conducted concurrently with data collection, and continues after field observations are complete. Bogdan and Biklen (1992) define data analysis as "The process of systematically searching and arranging the interview transcripts, fieldnotes, and other materials that you accumulate to increase your own understanding of them and to enable you to present what you have discovered to others. Analysis involves working with data, organizing them, breaking them into manageable units, synthesizing them, searching for patterns, discovering what is important and what is to be learned, and deciding what you will tell others." Analysis of data while still in the field involves the following processes:

1. Once the focus of the study is narrowed, narrow the scope of data collecting;
2. Analyze the data to help determine what type of study to do (although this is best done in advance of data collection and analysis);
3. Develop analytic or framing questions;
4. Plan data collection sessions in light of what you still need to find out;
5. Write and keep track of 'observer's comments' as analysis progresses;
6. Write memos to yourself to record your progress;
7. Try out ideas and themes on informants;
8. Begin exploring the literature while in the field;
9. Play with metaphors, analogies, and look for themes or patterns;
10. Use visual devices to organize ideas, concepts, etc. (Bogdan and Biklen, 1992).

Analysis of data after fieldwork usually involves organizing the data into different categories and developing a coding strategy to help with analysis. In my study, analysis

Table 11 The Interpretive Framework



of the data was done using the coding chart found in Table 2. Specific dimensions of scientific literacy were numbered and lettered to provide the coding scheme for data analysis. The codes were applied to fieldnotes, interview transcripts, student work samples, and curriculum documents in order to identify themes and patterns in the data.

The coding table represents the MEGOSE conception of scientific literacy, and includes the following dimensions of scientific literacy:

•Activity;
•Knowledge;
•Real-world contexts.

Other sections of the table were developed as I began preliminary coding of fieldnotes and interview transcripts. Although the "knowledge" dimension includes 'habits of mind,' the habits of mind were not clearly delineated in the MEGOSE document. Therefore, this section of the table, codes a-i, was taken directly from Science for All Americans. This provided much more flexibility in coding for "habits of mind." The technology and other codes contained in the table were also added to the framework as a result of coding interview transcripts. Much of what Ms. Brook actually did in the classroom and then shared with me in discussions did not lend itself to the original categorical dimensions in the table. To continue coding the data, I added necessary codes until the table was more relevant to the data collected. It was also necessary to add codes to the table because in analyzing data, I was searching for patterns. For example, Ms. Brook frequently emphasized the importance of the use of language in students' study of science. While MEGOSE stresses that in using scientific knowledge, information is shared in the language and activities of a particular community, use of correct scientific language is not included in the Dimensions of Scientific Literacy figure on page nine in MEGOSE. However, usage of scientific language is described in the text of MEGOSE, and thus I added the "D" code, "General Use of Language."

Table 12 MEGOSE Dimensions of Scientific Literacy Coding Table for Data Analysis

ACTIVITY	Preliminary Technology Codes
Using Scientific Knowledge 1) describing 2) explaining 3) predicting 4) designing **Constructing Scientific Knowledge** 5) asking questions 6) solving problems 7) interpreting text and data 8) reconstructing knowledge **Reflecting on Scientific Knowledge** 9) justifying 10) criticizing 11) describing limits 12) making connections 13) taking perspectives 14) describing S-T-S type issues **KNOWLEDGE OF..........** 15) nature of science & technology 16) key concepts and theories of science 17) historical roots of science & tech 18) habits of mind ----------------------> **REAL-WORLD CONTEXTS** 19) human societies 20) technological systems 21) the earth and space 22) physical systems 23) living systems **Other Codes Used** 24 = Conducting an Experiment 25 = Science integrating w/ other subjects 26 = Hands-on, active engagement	T1 = Using Internet to find something out, search for information T2 = Using hardware and/or software to research or solve a problem T3 = General accessing of information using technology T4 = Using interactive multimedia in science related projects **SCIENTIFIC HABITS OF MIND** a)respect for use of evidence & logical reasoning b)skepticism in evaluating claims & arguments c)balanced beliefs about social benefits of science d)positive attitude to science, using tools & instruments, thinking critically e)computational skills, mental calculations & estimates, gauge reasonableness of a computation or estimate f)ability to measure accurately & use a computer to store/retrieve information g)ability to communicate verbally & in writing in expressing & organizing ideas h)ability to read & comprehend science & technology news in the popular media i)ability to critically judge assertions made by texts, media, etc. and to subject their own assertions to same kind of scrutiny. A = General real-world context B = General knowledge category C = General science or tech activity D = General use of Language E = Equating being SL with effective citizenship & functioning in world

Similarly, the MEGOSE section of the coding schema was essentially void of specifics about technology. Eighteen "f" came closest to providing a technology code, but that fell far short of allowing one to code adequately the types of instructional technology work that were prevalent in Ms. Brook's classroom.

Because examining teaching and learning in pursuit of scientific literacy was the central purpose of this study, current science education policy documents have been key in informing the study. The "Dimensions of Scientific Literacy" Coding Table is primarily derived from MEGOSE, which is largely based on Science for All Americans. Similarly, the Interpretive Framework stemmed largely from chapter two of the National Science Education Standards (NRC, 1996). The National Science Education Standards provide an overview of current reformers' conceptions of scientific literacy, and chapter two specifically addresses the standards appropriate for good science teaching vis-a-vis: teaching, learning, and curriculum. This study's literature review in chapter two provided analysis of each of the three science education policy documents discussed here, specifically framing their conceptions of scientific literacy. While all three policy documents cited here deal specifically with scientific literacy, I utilize them in two ways:

1. As stated, the MEGOSE (1991) and Science for All Americans (1990) literature provided specific "Dimensions of Scientific Literacy" that were useful in the construction of a chart for coding the data;

2. The National Science Education Standards (1996) provided more detail regarding standards for exemplary science teaching. Thus, the National Science Education Standards' view of exemplary science teaching framed the study's focus on Ms. Brook as an exemplary science teacher.

Because my study largely focused on the role of the teacher in implementing a technology-rich curriculum, I see a strong link between what I have observed in Ms. Brook's classroom throughout data collection and the science teaching standards described in chapter two of the National Science Education Standards. Thus, the interpretive framework was largely constructed based on the National Science Education Standards for exemplary science teaching.

Qual

Afte

and a

with

claim

Strau

analy

comp

data a

comp

field

unit o

Categ

gener

cons

Qualitative Data Analysis Using the Constant Comparative Method

After I had collected a sufficient amount of data, and during data analysis both in the field and after completion of fieldwork, it became necessary to begin to make sense of the data with the ultimate goal of producing a report of the findings. In moving from the data to claims or findings, I used the constant comparative method of data analysis (Glaser and Strauss, 1967; Maykut and Morehouse, 1994). The constant comparative method of analyzing qualitative data combines inductive category coding with a simultaneous comparison of all units of meaning obtained from the data (Glaser and Strauss, 1967). As data analysis progressed, units of meaning that related to the research questions were compared to all other units and grouped with similar units of meaning. For example, as fieldnotes were coded, statements, descriptions, questions, and comments relating to one unit of meaning, scientific literacy for example, were grouped together and categorized. Categories were continuously refined, with some being discarded, changed, or new ones generated as the analysis progressed. Maykut and Morehouse (1994) illustrate the constant comparative method of data analysis below:

The Constant Comparative Method of Data Analysis

Inductive category coding and simultaneous
comparing of units of meaning across categories

↓

Refinement of categories

↓

Exploration of relationships and patterns
across categories

↓

Integration of data yielding an understanding of
people and settings being studied

I describe this data analysis method as a series of steps, but in reality these steps occur simultaneously, with analysis generating more questions, data collection, and coding (Bogdan and Biklen, 1992). In beginning this process, I first coded the data by using the number and letter codes in the MEGOSE Dimensions of Scientific Literacy Coding Chart. This process facilitated identifying units of meaning from the words and actions of the study's participants as well as from curricular documents and other data. Units of meaning are framed by the researcher's focus of inquiry. For example, anything to do with scientific literacy, use of instructional technology, technology-rich curricula, scientific inquiry, or exemplary science teaching would comprise a unit of meaning as it pertained directly to the focus of the study. Units of meaning in my data consisted of fieldnotes of classroom observations, descriptions from the Flamingowatch curriculum guide and electronic media, and interview responses from Ms. Brook. The length of units of meaning range from one sentence to several paragraphs. Longer units tended to emerge from interviews because Ms. Brook was encouraged to give full descriptions of her philosophies, teaching strategies, and experiences. Thus, she tended to respond to many questions by telling stories.

The data were labeled as to specific units of meaning, dated, and organized in chronological order. Many researchers then physically cut and paste the units of meaning from the data set and attach to 5" by 8" index cards. Each index card is labeled according to the specific unit of meaning. This allows cards to be sorted and categorized according to a theme or focus of the study. In my study, I did the cutting and pasting electronically by utilizing the word processor. Each unit of meaning was first cut, and then electronically pasted under the appropriate research question. Many units of meaning were pasted under more than one research question, especially if they were lengthy. Maykut and Morehouse (1994) refer to this process as unitizing the data.

After electronically unitizing the data, I printed hard copies of the unitized data under each research question. I then reproduced a copy of the study's interpretive framework onto a large poster and taped it to the wall. I then sorted through all the unitized data sheets searching for recurring concepts or themes, and grouped those units together. For example, interdisciplinary curriculum, global perspective, use of language, Internet use, scientific inquiry, etc. represent thematic representations of data categories. This process of cutting, pasting, and categorizing units of meaning follows:

After categorization, all data sheets were taped to the appropriate section of the interpretive framework. As analysis progressed, and the study began to focus more on Ms. Brook as an exemplary teacher, categories of data would change, with new units emerging and other units being omitted.

In the process of refining the categories and rearranging the units of meaning, I wrote assertions which emerged from the data (Erickson, 1986). Campbell (1993) defines an assertion as: "A statement about a cultural or social organizational pattern which you feel obtains in the settings in which you have been conducting your study." Put another way, assertions are "statements of fact derived from a rigorous and systematic analysis of the data" (Maykut and Morehouse, 1994). Each assertion was printed off, and taped to the interpretive framework on the wall.

The constant comparative method of data analysis involved the development of grouped data cards, and assertions keyed to the study's interpretive framework and research questions. As the study progressed, and its focus narrowed, the number and type of assertions also changed. Assertions were eliminated from and added to the study as data analysis progressed to interpretation and reporting of the findings. While some assertions stood on their own, some were related and data analysis led to identifying salient patterns or relationships, and grouping the assertions into appropriate sections of the study, thus leading to the findings.

Card 1

Internet Use

lets go on to AOL and find out exactly where these floods were occurring.
[SB Interview: 1-11-95]

Code: T1

In teaching that Netscape thing, the object there was to teach that this is a tool available to you, and here's what you can do with it. [SB Interview: 2-17-95]

Code: T1, T2

Card 2

Scientific Literacy

The stuff we're working with, the classmates are talking about it, listening to the story, being able to say it, and explain what they're talking about.
[SB Interview: 2-17-95]

Code: 1, 2

Even if they don't know what the answer is, that they would be able to make some kind of prediction or some kind of assumption based on the data that is available.
[SB Interview: 1-11-95]

Code: 3, 7

Figure 2 Examples of Unitized Data

The final step in the constant comparative method of analysis was to develop analysis and interpretation relating to the assertions which led to the study's findings. In this process, I provided evidence from the data that supported the assertions, and related the findings of the study to what has been done in this field of study in the larger sense. Writing up the findings by using the constant comparative method also led to rethinking of the data, and yielded new insights into the study at various points of analysis. This new understanding helped frame the final chapter in terms of discussion of the implications of the study.

Chapter four presents analysis, description, and interpretation of the data described in chapter three. Assertions are logically organized and keyed to the interpretive framework. Interpretation provides a close link between the findings and the literature reviewed in chapter three, thus linking the study to other research done in this field of study.

CHAPTER 4

TEACHER KNOWLEDGE, VALUES, AND BELIEFS ABOUT SCIENTIFIC AND TECHNOLOGICAL LITERACY

Introduction

The purpose of this study was to observe the classroom interactions of a fourth grade teacher and her students as they utilized instructional technology in pursuing scientific literacy. One of the primary tools used in this pursuit was instructional technology: the use of multimedia to implement a science curriculum that was "technology-rich."

Hawkins (1974) suggested that teaching must facilitate inquiry, promote the active engagement of students in the learning process, and provide curriculum that is substantially of interest to both students and the teacher. This view is supported by the NSES view of exemplary teaching, and science curricula that promote inquiry (NRC, 1996). In this chapter, I used the NSES Science Teaching Standards, the K-4 Science Content Standards (NRC, 1996), and other literature to guide my analysis and interpretation of data concerning Ms. Brook's teaching and learning, and her view of scientific and technological literacy.

In chapter three, I described the process of moving from claims to conclusions and providing evidentiary warrants for assertions. In the next four chapters, I examine assertions which closely correspond to the research questions, and report the findings of the study. The next four chapters are organized in parallel with the interpretive framework. I report in turn on teacher knowledge, values, and beliefs about:

- Scientific and technological literacy in Chapter 4;
- Teaching and learning in Chapter 5;
- Instructional technology in Chapter 6; and
- Scientific inquiry in Chapter 7.

Each chapter is organized by presenting the relevant research question(s), followed by an analysis and interpretation of the data, and concludes with a report on the findings.

Scien

teach

and

man

educ

the i

the Y

was

Scie

seem

grad

and

sta

sa

s

tech

Scientific and Technological Literacy

If scientific literacy is the goal of science education in America's schools, then K-12 teachers of science themselves need to be capable of teaching for conceptual understanding and incorporating the dimensions of scientific literacy into their science units. Although many elementary teachers have been traditionally ill-prepared to meet this challenge, educational reform efforts and our ever-increasingly technological environment are creating the impetus for more and better science teaching, especially at the elementary level.

In discussing current science reform documents with Ms. Brook, I told her I used the MEGOSE conception of scientific literacy to frame my study. Ms. Brook told me she was familiar with MEGOSE, having seen and used it on several occasions during the Science Education in Michigan Schools (SEMS) workshops she had attended, and having seen a copy of it at Jefferson School. Ms. Brook spoke approvingly of the MEGOSE goals and objectives, however she did not actively use MEGOSE in her lesson planning and implementation. During the course of the study, we did not specifically discuss the standards published by the NRC. In this study, I do not argue that Ms. Brook holds the same goals as the policy documents that frame this study. However, because the NRC standards are very influential on a national level and the MEGOSE goals and objectives are required of teachers in Michigan, both documents are accepted by the scientific and educational communities as a norm in teaching for scientific literacy. Thus, I wanted to compare what Ms. Brook actually did in the classroom to what the reform documents recommend vis-a-vis science teaching and learning.

Research question 1:
How does this elementary teacher view scientific literacy
and its connection to technological literacy?

Relevant Data, Analysis, and Interpretation

This section focused primarily on Ms. Brook's views on scientific and technological literacy. It also addressed what it means to be scientifically and technologically literate. Scientific literacy encompasses an understanding of science, mathematics, and technology (Hamm, 1992; AAAS, 1990). In pursuing scientific literacy through using instructional technology, Ms. Brook is an outlier in her profession (Jackson et al., 1994). Little has been written about how elementary teachers integrate instructional technology into science teaching, in part because so few elementary teachers are actually doing it. This is not to fault elementary teachers because there are many impediments to using instructional technology in classrooms (Becker, 1994; Cuban, 1993). For that reason, this study has much to contribute because Ms. Brook has worked around the roadblocks in utilizing instructional technology to pursue scientific literacy. How does she view scientific literacy and its connection to using instructional technology to teach science? I examined this question in this section. The following quote from Ms. Brook provides insight into her thinking:

> Considering what's going on in their world right now, the issue of science is Everything (her emphasis) right now...far more now than even two years ago. It just keeps...the whole issue of science and knowing what's going on with the world...it is critical that these kids understand and that they know how to find out about things. We just saw a video on the flood happening right now in California and we spent about ten minutes on what's causing this - cause and effect issues, the earth's atmosphere and how it's affecting California right now. All that kind of stuff started coming in and it's all science...For them to even be a part of the world they live in right now they have to know that stuff. The whole issue of knowing more and more about science is just critical for their functioning in this world.

In this passage, Ms. Brook established a rationale for educating scientifically literate citizens that mirrors those presented in chapter two. Ms. Brook's reference to the importance of students understanding scientific aspects of current events in their lives is consistent with the views of Hazen and Trefil (1991); and Flaste (1991). Flaste (1991) argued that scientifically literate citizens would understand scientific concepts portrayed in the news media. Hazen and Trefil (1991) argued the importance of citizens knowing about their natural world and stated that scientifically literate people needed to be able to understand scientific and technological issues that effect their lives. In this passage, Ms. Brook reiterated the idea that students' knowing about science was <u>critical</u> in order for them to function in their world and be effective citizens. This statement is in concert with the rationale that scientific literacy should be the goal of all school science and that scientifically literate citizens are necessary to promote the wise use of science and technology (AAAS, 1990; NRC, 1996).

What separates Ms. Brook from many elementary science teachers is that she follows this rationale through by implementing technology-rich science units that incorporate the dimensions of scientific literacy described in MEGOSE (MDE, 1991). In discussions with Ms. Brook, I determined that helping students learn enough about science and technology to equip them for the 21st century was her goal.

Ms. Brook's Views on Scientific and Technological Literacy

Because Ms. Brook does not view science as a separate subject, but rather one part of an integrated curriculum, it is somewhat difficult for her to distinguish scientific literacy from literacy in a more general sense. Similarly, Ms. Brook viewed using instructional technology as a tool to accomplish scientific inquiry. Thus, she did not distinguish a technological literacy separate from the processes of science and scientific inquiry. In contrast, both the AAAS (1990) and the NRC (1996) describe the importance of students knowing about the nature and principles of technology. However, both the AAAS and the NRC describe knowledge of technology as being a component of scientific literacy. The NRC (1996) describes the close relationship between science and technology and defines "instructional technology" as: instructional technology being the tools to conduct inquiry and understand science. Thus, Ms. Brook's view of the purpose of instructional technology is consistent with that of the NSES.

Because this study takes the view of the AAAS (1990) that scientific literacy encompasses knowledge of technology, and because Ms. Brook does not recognize technological literacy as a distinct literacy, I do not focus on technological literacy as separate from scientific literacy. However, because Ms. Brook often emphasized utilizing instructional technology in accessing and sharing information, I infer she would view that ability as representative of technological literacy. How does that view compare to other views of technological literacy?

The NSES (NRC, 1996) state that scientific literacy is achieved through pursuing scientific inquiry. In the passage below, pursuing design is described as being parallel to science as inquiry. Thus, in Content Standard E, the NSES (NRC, 1996) describe technological literacy this way:

> This standard emphasizes developing the ability to design a solution to a problem and understanding the relationship of science and technology and the way people are involved in both. This standard helps establish design as the technological parallel to inquiry in science. Like the science as inquiry standard, this standard begins the understanding of the design process, as well as the ability to solve simple design problems. (p. 135)

Content Standard E does not describe the ability to use instructional technology as a component of technological literacy. Rather, it places heavy emphasis on children designing solutions to technological problems. Thus, the standard would not go far enough to satisfy Ms. Brook's ideas about what technologically literate students would be able to do.

In chapter two, I reviewed the SFAA (1990) view of the nature and principles of technology. In Benchmarks for Science Literacy, the AAAS (1993) provides grade level benchmarks indicating what students in grades K-12 should know about technology. The Benchmarks (1993) acknowledge that at present, technology as a discipline or content area is not in the nation's science programs, and thus most students fail to learn about technology principles and issues. Chapter three of Benchmarks recommends what students should know about technology, which presumably would make students technologically literate (AAAS, 1993). Following are examples of the grades three through five technology benchmarks:

> Technology and Science - Technology extends the ability of people to change the world: to cut, shape, or put together materials; to move things from one place to another; and to reach farther with their hands, voices, senses, and minds. The changes may be for survival needs such as food, shelter, and defense, for communication and transportation, or to gain knowledge and express ideas. (p. 45)

> Design and Systems - There is no perfect design. Designs that are best in one respect (safety or ease of use, for example) may be inferior in other ways (cost or appearance). Usually some features must be sacrificed to get others. How such trade-offs are received depends upon which features are emphasized and which are down-played. (p. 49)
>
> Issues in Technology - Technologies often have drawbacks as well as benefits. A technology that helps some people or organisms may hurt others - either deliberately (as weapons can) or inadvertently (as pesticides can). When harm occurs or seems likely, choices have to be made or new solutions found. (p. 55)

Like the NSES view of technological literacy, Benchmarks describes what students should know about technology, but does not address students' use of instructional technology in classrooms (AAAS, 1993) .

In contrast, Grejda and Smith (1994) describe eleven standards for educational (instructional) technology that all teachers should be able to achieve. These standards were submitted to the National Council for Accreditation of Teacher Education (NCATE) by the International Society for Technology in Education (ISTE). These standards correspond closely to Ms. Brook's use of instructional technology, and thus provide a framework for thinking about technological literacy in a different way. All eleven standards listed by ISTE are particularly relevant to this study, and according to ISTE, all teachers should be able to:

> (a) evaluate and use computers and other related technologies to support the educational process;
>
> (b) apply current instructional principles, research, and appropriate assessment practices to the use of computers and related technologies;
>
> (c) explore, evaluate, and use computer technology-based materials;
>
> (d) demonstrate knowledge of uses of computers for problem solving, data collection, information management, communications, presentations, and decision making;
>
> (e) design and develop student learning activities that integrate computing and technology for a variety of student grouping strategies and for diverse student populations;
>
> (f) evaluate, select, and integrate computer technology-based instruction in the curriculum of one's subject area(s) and or grade level(s);
>
> (g) demonstrate knowledge of multimedia, hypermedia, and tele-communications activities to support instruction;

> (h) demonstrate skill in using productivity tools for professional and personal use, including word processing, database, spreadsheet, and print/graphic utilities;
>
> (i) use computer-based technologies to access information to enhance personal and professional productivity;
>
> (j) identify resources for staying current in applications of computing and related technologies in education; and
>
> (k) apply computers and related technologies to facilitate emerging roles of the learner and educator. (Grejda and Smith, 1994, p. 779)

This study's findings, as reported in chapters four and five, show that Ms. Brook's teaching demonstrated her ability to achieve most if not all of these standards. Thus, although she did not specifically define her personal view of technological literacy, her teaching corresponded to the ISTE standards of technological literacy described by Grejda and Smith (1994).

Chapter two outlined different conceptions of scientific literacy. In the previous section, Ms. Brook stated that she was in agreement with the principles and views expressed in <u>MEGOSE</u>. In the section below, I probed more deeply into Ms. Brook's thinking about scientific literacy. I began by asking how she viewed <u>scientific</u> literacy as opposed to just <u>literacy</u> in a general sense. I was also interested in her view of what a scientifically literate school graduate would be like. Ms. Brook responded to my inquiry in this way:

> Or mathematically literate, or technologically literate or......it's all just different strands ...different kinds of literacy......we hope our students will be literate in every strand but yeah......you can have a student who has read every classic but really doesn't know or know how to access information through technology or anything like that......you could say that that child is very literate, but again they would be technologically illiterate.....

In this passage, Ms. Brook again mentioned a theme that emerged throughout this study: that scientifically literate students needed to know how to <u>access information</u> by using technology and other sources. She concluded that being unable to access information through technology would render a student "technologically illiterate." The <u>NSES</u> promotes the use of instructional technology by students and teachers to conduct inquiry and understand science (NRC, 1996). By inference, one could then state that a necessary component of scientific literacy would include the ability to utilize instructional technology.

As Ms. Brook distinguished between various literacies, I reminded her that earlier she had talked a lot about scientific literacy involving students being able to analyze, interpret, and make sense of data, and that she had emphasized "using scientific language in a correct and precise way." Upon reflection, Ms. Brook agreed, but then spoke again about her view of science teaching and learning being highly interdisciplinary, and was unclear about how scientific literacy fit in:

> Well, it's a different strand of experiences and learning. I mean, every....well you can separate out scientific literacy from all those other strands, at this level, they're employing math, reading, and everything else while they investigate anything in science....

In this passage, Ms. Brook described scientific investigation as involving an integrated approach, where math, reading "and everything else" are brought to bear on the investigation. MEGOSE argues that to achieve the objectives of scientific inquiry, learning must be interdisciplinary (MDE, 1991). In Benchmarks for Science Literacy, the AAAS (1993) defines interdisciplinary curriculum as being on a continuum, with the most common form related to combining subjects within a discipline (chemistry and biology for example). On the other end of the continuum, the AAAS (1993) describes interdisciplinary curriculum in a way that seems to correspond to Ms. Brook's view of it:

> ...and for still others it is even more sweeping, reaching into the arts and humanities. (p. 320)

At this point, I directed the conversation toward Ms. Brook's thinking about how one teaches for scientific literacy. What types of curricular activities and/or teaching strategies might promote scientific literacy? Her response focused on the detrimental effects of relying on science textbooks. I asked her to elaborate:

> They just.......you know the textbook puts things into words that you hope the children think. It's just words on paper....it's not experience, it's like boring comprehension questions on a worksheet (using the book) it doesn't mean that they get it at all!

In this passage, Ms. Brook argued that dependence on textbooks would not promote the type of understanding nor active engagement with science described in MEGOSE (MDE, 1991) or the NSES (NRC, 1996). For example, the NSES describe understanding in this way:

> Understanding science requires that the individual integrate a complex structure of many types of knowledge, including the ideas of science, relationships between ideas, reasons for these relationships, ways to use the ideas to explain and predict other natural phenomena, and ways to apply them to many events. Developing understanding presupposes that students are actively engaged with the ideas of science and have many experiences with the natural world. (p. 23)

Clearly, Ms. Brook does not view textbooks as effective in promoting the type of deep understanding described in the NSES.

I suggested that many textbooks provided activities of all sorts. My intention was to probe her thinking about why specifically she felt textbooks were problematic in science learning. She replied:

> Oh, sure, yeah......you know it's interesting - I'm watching how these kids are learning force right now and one thing I feel really diligent about is using the correct language with them. If we're talking about anything that's happening.....that the language has to be very specific to the scientific stuff that we're doing. So, if I use the word *accelerate* I have to mean exactly that......the second thing is that before they experience something you have to have a lot of time to talk it through and imagine and predict and do a lot of the thinking process out loud with the kids....uh, we'll spend 35 minutes talking about the experience and about 15 minutes doing the experience....and that seems to be pretty worthwhile......and, as a review, I'll use the textbooks or piece of scripted material and when I'm using that I'm reinforcing the experience.

In this passage, Ms. Brook described her use of textbooks as a strategy to review something students had experienced.

In Ms. Brook's view, the pursuit of scientific literacy would necessitate "putting aside the textbook." She felt textbooks did not promote the experiential learning that is a necessary component of scientific literacy. I asked Ms. Brook to describe a specific type of curriculum that she felt did promote scientific literacy. She responded by describing how one student brought a toy race track to class and how the class played with the race track for an extended period of time. Following is Ms. Brook's description of how this activity promoted scientific literacy.

> I'll give you an example.......we were discussing force and motion and this one kid in class just lit right up and she said that for a Christmas gift she got one of those race tracks and she said that this race track was perfect for force and motion and she was using all the language that we were using in class in our science lessons and ......a great example....next day she comes in school and she's got the whole thing in a big crate and she sets the thing up....Greg, we had more fun with that race track....we ended up..she set the whole thing up at recess so by 10:40 the thing was ready to go. All of us, all 25 of us gathered around this race track and first she let a few cars go around and kids had some fun with it, then we started talking about it and we ended up talking ....you know, the kids wanted to know..... someone mentioned the word momentum, which was going to be my next lesson anyway so I got excited and kept following the kid up on that whole thing and then they sort of came up with "what if we put the cars here....what would happen.?" Or, what if we put the car here and we did this then what would happen? And out of the 25 kids, they kept coming up with different ways to modify this activity and experience. They wanted to know....and they came up with 5 or 6 versions of that same thing. It's exactly what a good scientific experiment would be......to come up with as many variables.

Ms. Brook's description of this race track activity highlighted aspects of scientific literacy that are consistent with the MEGOSE (MDE, 1991) dimensions of scientific literacy and the NSES' (NRC, 1996) view of scientific inquiry. In this passage, Ms. Brook mentioned that students were not only speaking in scientific language, but were also asking lots of questions such as "what if we put the cars here...?" Ms. Brook compared this discussion to how a good experiment would be set up. She mentioned that students were, in fact, discussing use of variables in trying to predict how the race cars would perform. The students were talking a lot, giving descriptions and asking questions. This passage also is a good indicator of what it looks like for students to be actively engaged with science: sitting on the floor, examining apparatus, asking questions, developing scientific discourse in which information and ideas are shared, and pursuing scientific inquiry.

What was Ms. Brook's role in the activity? I asked whether she thought her students explicitly understood that this type of activity might promote scientific literacy.

> Well, you know I was guiding them because in the course of all that I would say words like 'well what if we change this variable?' Variable is not in language they understand but they knew exactly what I meant even

> without defining it, then, the car had not even run yet. And then there were kids getting ready to do it and I just kept halting them for theatrics and at one point I just said 'wait, I want Patti to do this experiment not one time but I want her to do it 100 times' and the kids went whoa.....but Tom right away started nodding his head and I knew he understood why and he followed up and said "yes, because to do an experiment once, it's only going to show you what happened that one time, if you do it 100 times.......he basically put it into words why the experiment is conducted several times over. They talked for 20 minutes straight on this one activity before they even let the car go.....and then we did the car and did it a few more times and it was so effective because they had a chance to talk and talk and talk and I wanted to see how long I could keep the kids talking before I let the car go......one kid said "why don't you let the car go" and 5 or 6 other kids said "no, not yet, I want my prediction made first" and that's exactly where you want the kids to be......

Teachers of science guide and facilitate students' learning by supporting inquiries while interacting with students, orchestrating discourse about scientific ideas, and modeling the skills of scientific inquiry (NRC, 1996). Teachers of science also design and manage learning environments that provide students with the time, space, and resources needed for learning science (NRC, 1996). In the passages above, as Ms. Brook related the active engagement her students had with the race track, she described her role as providing guidance or scaffolding. She stated "I was guiding them," by asking questions such as "well, what if we change this variable?" She also felt her questioning was calculated to keep their interest and motivation high. She stated she "kept halting them for theatrics." This process of asking questions, modeling scientific thought, encouraging scientific discourse, are all behaviors I witnessed many times in Ms. Brook's classroom. Ms. Brook believed the race track vignette provided a good example of the type of activity that promoted scientific literacy. She did not specifically relate the components of the activity to MEGOSE or the NSES, but her description of the activity highlighted several dimensions of scientific literacy described above.

At this point, it seemed appropriate to bring up the contrast between the race track vignette described by Ms. Brook and how this topic might have been treated in a textbook. In many classrooms, students would have read about force, motion, and momentum in the textbook, memorizing the definitions. They may have looked at diagrams or illustrations of the concepts. In Ms. Brook's classroom, she and the students were on the floor, physically engaged with an apparatus that allowed students to manipulate it over and over - asking questions, making predictions, and discussing the concepts with each other. I commented that the example seemed to epitomize teaching for scientific literacy and asked Ms. Brook to comment:

> Well, that's it, I mean, the experience of it, I mean that's as far as I can go......other than taking them to a race track but even that would've been less effective because with this they actually experienced the activity, not watched it.....the tug of war is another example - I could do the whole balance thing in several different ways but, that's the whole experience of it.

The focus of this passage was how curricular activities promote scientific literacy. Ms. Brook's bottom-line, which she expressed consistently throughout this study is "the more activity the better." Actively engaging students in hands-on activities that are conceptually grounded are paramount in pursuing scientific literacy (NRC, 1996).

In summarizing her views about scientific literacy, Ms. Brook acknowledged that the scientifically literate person would be able to:

•analyze;
•interpret data;
•use science-specific language.

Ms. Brook also described scientifically literate students as being able to discuss scientific concepts using correct language, understand how to know about and interpret events in their real world, access information using technology, and be active in the doing of science. While her views expressed in this section do not address all dimensions of scientific literacy, they do correspond to some of the dimensions of scientific literacy described in MEGOSE (MDE, 1991) and the NSES (NRC, 1996). Further, her views on scientific literacy and how she utilized instructional technology to pursue scientific literacy manifest themselves in different sections of this study.

Summary of Findings

Ms. Brook believes scientific and technological literacy cannot be divorced from literacy in a general sense. Using instructional technology to study science is a process in which science is integrated with other subjects (MDE, 1991; AAAS, 1993). She described this as "different kinds of literacy." In specific response to research question one, Ms. Brook viewed sciencific literacy holisitcally. She was reluctant to define scientific literacy, prefering to describe what she felt were important components of scientific literacy. Even though she was very familiar with MEGOSE, and acknowledged the district's science objectives were closely related to those in MEGOSE, she did not utilize MEGOSE in describing her views of scientific literacy. Along with the proper use of scientific language, Ms. Brook emphasized the importance of students being able to make predictions and ask questions based on available data. Below I elaborate on the components of scientific literacy Ms. Brook identified.

When pushed to think specifically about scientific literacy, Ms. Brook identified several components of scientific literacy that correspond to those described in the literature. A primary use of instructional technology is to assist students in accessing information. If one was not capable of doing so, one would be "technologically illiterate," and thus not be as scientifically literate as possible. Thus, in response to research question two, Ms. Brook viewed instructional technology as a vital link between scientific and technological literacy. In order to be technologically literate, students needed to be able to utilize instructional technologies to access information. That information would then be shared with peers in the process of scientific inquiry.

In teaching for scientific literacy, Ms. Brook suggested de-emphasizing textbooks as they did not promote understanding of science concepts, but rather memorization of facts. Use of textbooks did not prepare students for understanding their natural world. Ms. Brook described her role as a teacher as non-didactic; she viewed herself as a guide, facilitating learning, promoting scientific discourse among students (NRC, 1996).

Ms. Brook identified the correct use of scientific language as an important component of scientific literacy and encouraged students to discuss, explain, and predict while participating in scientific discourse. This view was described in detail in the race track vignette. While facilitating scientific discourse, Ms. Brook felt it important to model for children how to ask appropriate questions, and share information with each other. Both oral discourse and writing to develop scientific literacy played important roles in actively engaging students with the science curriculum. I describe more about scientific discourse and utilizing instructional technology in writing activities in chapters five, six, and seven.

Finally, Ms. Brook emphasized her view that students should actively engage with the science curriculum (MDE, 1991). Scientific literacy was promoted when children were doing activities in which they interacted directly with apparatus, and with fellow students. As Ms. Brook put it, "The more activity the better." Ms. Brook's views about the role of students as active learners is described in more detail in the next section.

CHAPTER 5

TEACHER KNOWLEDGE, VALUES, AND BELIEFS ABOUT TEACHING AND LEARNING

Research question 2:
How does this elementary teacher view teaching and learning?

Research question 3:
How has this elementary teacher prepared herself for utilizing instructional technology in the classroom?

Relevant Data, Analysis, and Interpretation

As the NSES indicate, teaching is a complex process (NRC, 1996). While this section focuses on Ms. Brook's knowledge, values, and beliefs about teaching and learning, it does so by describing aspects of curriculum that she feels epitomize good science teaching. Thus, describing Ms. Brook's views on knowledge of teaching and learning are inextricably linked to her views on effective science curricula.

Much of the analysis in this section focuses on developing a descriptive case which allows the reader to get a good sense for the type of technology-rich science curricula Ms. Brook utilized, how she prepared herself to utilize instructional technology, and the impediments to using instructional technology. The analysis includes Ms. Brook's perspectives on teaching and learning.

Although the study is written section-by-section for the sake of organization and convenience, in practice it is difficult to separate a teacher's thoughts, feelings, and experiences into such neat categories. Thus, when Ms. Brook talks generally about teaching, she invariably integrates talk of students' learning, curriculum projects, her philosophy and educational background, etc. In other words, Ms. Brook views the education process holistically, with everything falling under the umbrella of teaching and learning. Ziman (1994) argues that this type of a holistic conception of science teaching is a basic principle of STS education and is relevant in thinking about tackling practical problems arising in society through scientific methods. Draina (1994) argues that teachers need to approach the integration of instructional technology into the curriculum from a holistic framework. The interpretive framework included in the study was designed to help fragment the holistic viewpoint into several "chunks," all of which contribute to answering the research questions in chapter 1 and to developing the case of how Ms. Brook goes about using instructional technology to teach for scientific literacy. The following quote sums up Ms. Brook's philosophy of learning and sets the stage for the findings of this study, which will uncover the details of the "journey" she describes.

> I'm on this journey too....this is my journey, to learn as much as I can! That's the journey that our children set, to learn as much as they can, and that's my journey too.
>
> Susan Brook
> May 11, 1995

In this quote, Ms. Brook refers to learning as a "journey" that students and teacher take together. Implicit in the quote is Ms. Brook's overall goal as a teacher, to learn as much as possible while on the journey. This study is about defining and describing the process as Ms. Brook and her students progressed on their journey of learning.

In chapter 5, the study's focus shifts from scientific literacy to establishing background information about Ms. Brook. Who is Ms. Brook as a science teacher and how does she view teaching and learning science?

Ms. Brook is an elementary generalist who is not a science major or minor. In fact, Ms. Brook's specialization is literacy, and she is also a professional writer. Ms. Brook is a poet, not a scientist, and thus it is not surprising that Ms. Brook views science teaching and learning from a conceptual framework closer to the humanities than the sciences. Her views on science teaching and learning are informed more forcefully from her own experience and preparation than from professional coursework.

In describing her philosophy about teaching and learning, Ms. Brook focused mainly on curricular issues, and how she thought about those issues. At one point, Ms.

Brook expressed to me that she loves thinking about curriculum - how it gets planned, how the different parts fit together, and how it gets implemented. In the following passage, Ms. Brook spoke about curriculum development and implementation metaphorically:

> You know, planning curricular projects is just like classical music, in which there's this piece that comes in like this and then this piece comes in like this...you know how they go like this?
>
> [moving her hands about in circles to demonstrate the metaphor]
>
> You can hear it when it happens, Mozart does it, Bach does it, Chopin does it some...there's this one we listen to at home that is so cool, um...he does it really well, I mean, I only have two hands to demonstrate, but if you imagine a whole orchestra you have 86 pieces all doing this together...that's what all this learning looks like sometimes. You very rarely come to the point where all of us are on the same note...but that's cool, that's a way of thinking that it's not chaos out there either...it's not a bunch of instruments just playing off in different directions...the direction is together, but I don't know where it is ending up.
>
> The thing about it being like a piece of music .....it sure isn't like a piece of music if you think of a Mozart or a Beethoven or something like that because you know those things are beautifully well placed and choreographed and fit sooooooo neatly (very emphatic)......you know when you hear a cello and a violin working together on a Beethoven piece, you know the blending and the way that it all fits you know from over here and over here (swirling her hands) and then suddenly those two instruments join together and continue like that......after a lesson you can say "Wow" there was a part there where this piece and this piece were going on and were dynamic and then that one part in that lesson where they blended together and suddenly it all made sense to those students and then it all diverged again.....then after a lesson you could say, that happened, like that Beethoven piece I was listening to, but I only would say that to myself after a lesson occurred. But you don't see it all pulled together like a composition until it's over with, you put in all the pieces, all the pieces you can think of ....it's almost like the piece comes out of it while it's happening, then maybe it's like a jazz improv.......you hear all these parts together and you know all these players are playing off of each other in order to make something happen and it's more improve.

Tobin and LaMaster (1995) and Gurney (1995) use metaphor to study teachers' conceptions of teaching and learning. Gurney (1995) argues that "an examination of personal metaphors reveals one's original world views in a way that literal language cannot" (p. 571). Tobin and LaMaster (1995) studied a novice teacher who described her role as a facilitator of learning metaphorically, using three different metaphors to describe her role as a classroom teacher. Thus, as Schon (1983) suggests, metaphor may be used as "a perspective or frame, a way of looking at things - and...a certain kind of process - a process by which new perspectives on the world come into existence" (p. 254).

The evidence presented in her metaphor suggests that Ms. Brook views curriculum as something that can be planned, up to a certain point, but the direction it heads and the final outcome will, in a sense, be discovered in the process. In this passage, Ms. Brook states that she has clear goals as to what she wants students to learn. Ms. Brook feels that in the teaching and learning process, many different "pieces" are playing at the same time, and "the direction is together." What isn't clear is how she and the students will get where they are going. She also accepts that a project's "grand finale" may materialize in a very different way than what was originally planned.

In the second part of her metaphor, Ms. Brook also makes an important distinction about how the "music might fit together." In her original description, she says that while all the different notes rarely are together, they are all heading in the same direction. In the second part of her metaphoric description, she describes teaching and learning as more of a jazz improv, where there is a tune, but all the pieces are contributing by playing off one another, as opposed to a more orderly Mozart piece where the score is orchestrated so that all the pieces are working together. Implicit in this passage is the idea that because she is not directing all students in the same direction at the same time, her teaching style is opposed to the "teaching is telling" paradigm.

Ms. Brook further describes how she moves the class in a certain direction by knowing how certain students can contribute to lessons by participating in particular ways. In describing how she facilitates the direction a lesson might go, Ms. Brook states:

> "There were several kids I didn't call on and for good reason too...if I want to go in a divergent way I probably call on Jeremy, and Frank, and Ellen. Peter is pretty analytical but then he will also change the direction of the discussion. If I want things clarified, I know who I can start calling on to help out with that kind of thing, so you kinda play to your audience a little bit. And that wasn't a random discussion that just happened. It was fairly organized."

Thus, Ms. Brook metaphorically views herself as the conductor of the orchestra. She realizes that sometimes orchestral members will improvise, but her choices of whom to call on can influence the direction of the improvisation. While the music has purpose and direction, sometimes a new score is created from the intended.

Assertions Regarding Teaching and Learning

Assertion 1
Ms. Brook views curriculum as needing a real-world connection to students' lives, and feels students' real-world should be expanded to represent a global perspective.

One of the major emphases of the MEGOSE conception of scientific literacy is that learning must have a real-world connection for students. In the MEGOSE guidelines to teachers on writing objectives for science units, each objective is related to the "real world," thus helping teachers envision what the authors mean by real-world connection. Because many students have never seen certain scientific phenomena such as atoms, or volcanoes, the real world connection is made through the use of pictures, diagrams, videos, and other representations (MDE, 1991). This real-world focus of curriculum emerged repeatedly in my conversations with Ms. Brook.

To many students, their school curriculum presents an amalgam of facts and skills that are fragmented, unconnected, and disjointed. In an attempt to make school curriculum more connected and meaningful, some educators have restructured curriculum by integrating the different subject areas (Beane, 1991). In looking through the data, it appears that Ms. Brook used the terms "integrated" and "interdisciplinary" synonymously. Another term that she frequently used to describe a curriculum's real-world emphasis was "connectedness," although she does make subtle distinctions between these terms. Benchmarks defines the term interdisciplinary in three ways (AAAS, 1993). In one definition, the term interconnected knowledge is used. Benchmarks defines the term this way:

> The students' experiences should be designed to help them see the relationships among science, mathematics, and technology and between them and other human endeavors. (p. 320)

Another definition of the term interdisciplinary which is relevant to Ms. Brook's comments below is coherence. Benchmarks defines coherence in this way:

> The students experiences need to add up to more than a collection of miscellaneous topics, whether under themes (everything about, say, salmon), disciplinary subject headings (Principles of Chemistry), or activities ("neat things for kids to do"). (p. 320)

I asked Ms. Brook to explain the distinctions in these terms, and she answered in this way:

> With interdisciplinary we're talking about all the different academic subjects we teach, but then interconnected goes beyond interdisciplinary, because in addition to being connected to all these academics, I think it has to be significantly connected to their REAL LIFE (emphasis by Ms. Brook) and that doesn't necessarily mean interdisciplinary...

As we continued to talk about the dimensions of scientific literacy and the connectedness of things to students' real world, I pointed out that I added some codes to the MEGOSE dimensions of scientific literacy, including integrated curriculum and effective citizens. Ms. Brook's ideas about connected, real-world curricula follows.

> GC: On a scale of 1 to 10, 10 being the highest, where do you think the importance of real world connections in curriculum is?
>
> An 11! I really do, because otherwise, what am I teaching them? A bunch of facts and details? You know, I can get those facts and details if I just go straight by the book or straight by a traditional curriculum and not have the connectedness happening. For one thing, the facts might not be valid learning for them. The kids could find that information for themselves if they needed to.
>
> The other piece of this that is important is the fact that real world problems have to be connected to THEIR (her emphasis) real world. That's a step closer and on top of that, once they have that then I want them to take some action towards being a responsible citizen. And that's not listed here but that's OK......"
>
> GC: When you say connectedness to all of it are you referring to science being integrated with other subjects or part of a big picture?
>
> Yeah. The Kobe project is a good example of that and so is the Flamingowatch come to think of it. In the Flamingowatch, all the stuff we did on the science end of it, the interdependence of the different animals, the issue of studying habitat, the information about the ecosystems, and all the physical stuff about the soda lakes and the qualities of each animal that make them suitable for the habitat in which they live, that's all, it sounds like

> really straight science. But then on top of it you put in there that information about the Masai tribes who are also sharing the same habitat and how they depend on each other and for instance how they hinder and benefit each other (the Masai and animals) so there are the social aspects of all of this too.
>
> The students have a real social sense. We're not just in science here but we're into the study of culture so a lot of this stuff we do under the label of social studies goes with the science. Uh, then for instance we can take even just the issue of say the rhino, or any of the animals and to think of the issue of poaching, which we worked on.....about how some people are acting irresponsible towards the animals and then we're onto the issue of values, what is important in the issues, etc. It's broader than the habits of mind stuff in that it's all so tied in. Shoot, it's connected in the way of what humans' responsibility is to take care of their world, so you better be an effective or a responsible citizen cause to me it's a character of, it's a value of education kind of thing, but I think it needs to be infused into all of this stuff in Flamingowatch and the other stuff we do. Let's see, we've just connected it to science and to social studies and to character education.....
>
> GC: Would you think the science learning would be less effective if it were not connected?
>
> Oh sure. So then where's the meaning? You could teach science as a bag of tricks, like Mr. Wizard, and that's fun, it's motivating, but that's it. That's OK. But you do a lot of separate ideas that are not connected. It is tough, because I keep striving to make all this stuff connected to not just their (students') real world but to expand what their real world is, you know? I have to make sure that I'm covering, and I don't like that word covering, but I need to make sure I cover what I need to cover. I need to teach what I'm required.

Ms. Brook stated the importance of connecting curriculum to students' real world. She then stated that one way of doing that was to integrate the concept of "responsible citizenship" into the curriculum. She described her students as having "a real social sense." DeBoer (1991) described three reasons for teaching socially relevant science. When science programs focus on the science occurring in students' real lives such as environmental issues, recycling, or about household objects such as appliances and the automobile, students are motivated to learn the science that relates closely to their daily lives. Science ceases to be in abstract form. Next, science should "inform and enrich the lives of individuals," and should lead to students functioning as effective citizens in a democratic society (DeBoer, 1991, p. 235). Finally, the teaching of socially relevant science is critical to the well-being of the human race. While DeBoer argued rather abstractly for teaching socially relevant science, the manifestation of his argument could be seen, for example, in this study's description and analysis of the Kobe Project (see chapter 6). Both the Kobe and Flamingowatch projects provided examples of Ms. Brook's students working on socially relevant scientific issues. Students worked on developing this social sense by working through some of the issues in the Flamingowatch curriculum: poaching, habitat destruction, different cultural groups' values, and humans' responsibilities in general. In working through some of these social issues in Flamingowatch, students discussed and debated the issues with each other. In other words, Ms. Brook's students worked collaboratively with each other to communicate and solve problems (MDE, 1991). Thus, Flamingowatch provided the conduit to connect effective citizenship, science, and social studies.

Ms. Brook also stated the importance of making connections in implementing curricula. Ms. Brook stated that science facts and concepts need to be connected, that students' ability to make connections was important. She felt the most important way to do that was to connect the curricular content to students' real world. In the passage above, Ms. Brook indicated that teaching science as a "bag of tricks, like Mr. Wizard," would not promote understanding because the activities were not connected. Her view of the importance of knowledge and ideas being interconnected, and connected to students' real lives is consistent with the Benchmarks description of interdisciplinary curriculum (AAAS, 1993).

In describing the interconnectedness of the content of the Flamingowatch project, Ms. Brook described the science content and how it was related to learning about the Masai people, and the social issues that arose from that curriculum. She also discussed her idea that issues emanating from East Africa are related to those that citizens in this state are confronted with. She used the Flamingowatch project to demonstrate how many different subject areas were integrated and relate to students' real world.

In describing her ideas about real-world curricular implications, Ms. Brook made an interesting comment which illuminates how she sees the larger picture of curriculum vis-a-vis the real world:

> I keep striving to make all this stuff connected to not just their real world, but to expand what their real world is, you know?

In proposing to expand the vision of her students, Ms. Brook again demonstrates that her view of learning is very different from that of those teaching using the traditional paradigm. While many teachers may have the same goals as Ms. Brook, they don't actually implement them as Ms. Brook does. Ms. Brook seems to be indicating that our real world has become much more global, that the interconnections within curricula can actually expand what one's real world is. This idea of an expanded vision of our world, especially for our students, was reiterated when I began to question how studying Africa, or Georgia, could be construed as real-world to students living in Jefferson.

The following conversation illustrates our discussion about this potential contradiction in terms:

> GC: How is something like the Okefenokee or Flamingowatch projects actually a real world activity that kids can relate to?
>
> Well, the wetland stuff is a key environmental issue here in the township. These kids live these issues.
>
> GC: Yes, but Flamingowatch emanates from Kenya. Some might wonder what makes that real world when our kids live here?
>
> Well their scope of the world sure has to be greater than Jefferson Township..." (said with incredulity)

Thus, Ms. Brook advocated curricula that enables students to think globally, to be connected to information, ideas, concepts, and issues far removed from their physical location in Jefferson, and yet to perceive those issues as having a real-world connection to their lives. In my notes, I made the following comment:

> SB's ideas about expanding students' vision of what the world is seems to me very visionary. She definitely is looking for connections that are global in nature, such as the Okefenokee project being related to students' wetland studies in Jefferson.

Yet, I continued to press about the idea of considering something in Africa as being relevant to Jefferson students' real lives. In doing so, I wanted to establish, in a sense, Ms. Brook's sincerity about the issue. Did she really feel that way, or was she using "real-world" as yet another educational buzzword? I asked Ms. Brook how Flamingowatch became real to students' lives:

> I don't know? (long pause) That's a good one! That's the kind of question that's going to haunt me until I think of an answer. How did I connect and make that unit part of their real world? I think I did it in a few different ways......sometimes you have to make it stretch, you know? That's ok too. Maybe in this case.....I wanted the children to know how to do research and it is a universal, life skill, not just a skill for 4th grade, but it is a life skill. So, a lot of the stuff we did in the Flamingowatch topic was to learn some research skills. The second thing is that we connected as a research team with kids in another school so there was some real world thing going on with them having to be a research team with kids from a neighboring district. Use the technology to do it, and just use the technology as an avenue to do that. I wanted them to be able to learn how to use technology and how to access information and we did that with AOL and lots of the files that we'd gotten on that stuff. And part of the science curriculum we're doing, we've studied the food chain, food webs, interdependence, and the Flamingowatch was a perfect avenue for that, um, we'd already learned about in a real comprehensive way the ecosystem of the wetland when we did Okefenokee so it would make sense to reinforce all that in the Flamingowatch unit. They understood it from a local perspective, now let's go to a more global sense and so it made sense to go to Kenya. Cause, we'd done ecosystem in a community frame, then a country one when we did Okefenokee, and now global with Kenya.
>
> GC: But when you say that Africa is a real world connection, I'm not sure...........
>
> SB: But Peggy (the Flamingowatch moderator) was here with us in the classroom by broadcasting from Kenya! When she said good morning students, she was talking to them live, and they knew she was live with them, WITH THEM! (her emphasis) They knew that! They knew that they were part of the small group of people throughout the world viewing her at that particular time and they knew she was talking directly to them.

Haunting as my question may have been, Ms. Brook did develop an answer to the question, and a convincing one that I feel illustrates nicely what science education reformers are talking about when they refer to curricula that has a real-world connection to students' lives (MDE, 1991). Bievenue et al. (1993) argue that using the Internet provides students a worldwide connectivity, one that offers a wealth of resources and forums to explore issues and access information. Integrating Internet use into the curriculum breaks the barriers of isolation many classrooms operate under and in a sense, brings the world to the classroom and the classroom to the world (Bievenue et al., 1993). In fact, Bievenue et al. (1993) argue that if K-12 education supposes to prepare students for the 21st century world, a major goal of scientific literacy, Internet use must become part of classroom teaching and learning.

There are many ways for this real-world connection to manifest itself in the classroom, and teachers do not necessarily have to engage in the implementation of technology-rich science units in order to accomplish the goal. However, the use of the Internet in science teaching does lend itself to establishing this global perspective Ms. Brook described and it does seem to help students develop connections to ideas, issues, and people who are far-reaching (Grejda and Smith, 1994). For example, I observed students on an almost daily basis using the Internet to discuss curricular issues with people from Italy, China, Japan, Peru, Alaska, Wyoming, California, etc. I also observed them using the Internet to search databases in other parts of the world. Students frequently talked about the power of the Internet in allowing them to expand their knowledge base by tapping into worldwide resources.

In describing students' collaboration on the Flamingowatch research project, the use of instructional technology to access information, and comparing that information to local issues, Ms. Brook described some of the ways to make curricular connections to students' real-world (AAAS, 1993; Grejda and Smith, 1994). She also emphasized the impact of the live, interactive portion of Flamingowatch in helping students see the connection between the Great Rift Valley and science in their local area. This connection between Flamingowatch and science study in their local area was bolstered, in Ms. Brook's view, by her students "connecting as a research team with kids in another school."

Finally, Ms. Brook also spoke of the concept of "connectedness" in a slightly different way. Regarding children's learning, she felt that students needed to feel "personally" connected to their learning. This is somewhat related both to developing ownership of the curriculum, and to the need for a real-world curricular connection. But the meaning seems to transcend both of those ideas. Below, Ms. Brook talks about students being "personally connected" to their learning.

> Look at these examples then. When I talk about Kobe it was the fact that they were able to help somebody else in a personal way and use technology in order to be able to do that and the China thing where they did see somebody else's writing and learn from a very different way of looking at that, and from the animal report having had the opportunity and the freedom to work together and design their projects the way they wanted to......the technology was sure a part of that because they used technology in order to make that happen but every single part of these projects had a personal, human connection that went with it that made it real to them. Maybe that's it. Maybe it's at the point where they had an opportunity to get connected with other kids while they're learning that makes that learning theirs. You can't be connected to somebody else and just not learn it, or you can't be connected to somebody else and have it be the teacher's learning and not yours.
>
> GC: If you didn't have the opportunity to implement the technology the way you do, how would you try to create those same feelings and experiences?
>
> Oh, it would be so much more difficult.........going through books would make it so much slower, and it's not nearly as fun. And, that kind of stuff was, those were the tools they were using and it made things immediate for them. You know when Vern called Frank that night and told him to tape the program off TV for the stuff they were doing at school, that's another PROFOUND (her emphasis) example of children having the sense that this is their learning and not my learning.
>
> In a real complex way because it's not just learning a bunch of facts but they have those same facts connected to other content within that, and because of the way Flamingowatch was set up they also had it connected to some much more complex concepts such as the concept of interdependence and the whole concept of culture, when you think of the people who live there. I think the kids had a really firm grasp of all that.

In this passage, Ms. Brook reflected about children's learning and in a sense reiterated her metaphoric description of children learning in their own way as they progress through the "journey" of learning. She clearly stated that the potential for learning was greater because each of the projects completed had some sort of personal connection for students. Ms. Brook described the <u>complexity</u> of students' learning, and the fact that their learning was based on conceptual understanding rather than memorization of "a bunch of facts" (MDE, 1991; NRC 1996).

Assertion 2
Ms. Brook created an interdisciplinary curriculum.

Many classroom teachers and administrators identify barriers to implementing interdisciplinary courses and curriculum units (Meier et al., 1996). Additional time, effort, and costs are associated with interdisciplinary units. Teachers inexperienced with interdisciplinary units often have trouble visualizing this type of teaching (Meier et al., 1996). However, science education policy documents such as MEGOSE (MDE, 1991) call for science courses to become more interdisciplinary in nature. A strong rationale for interdisciplinary learning is that students' real-world lives are not compartmentalized into segregated units. Students need to see the big picture, and be able to understand relationships and make connections (MDE, 1991; Meier et al., 1996). As Householder (1992) argued, problems in life require the use of many types of information and knowledge in order to achieve solutions. The idea that curriculum is defined by different subjects being integrated together, and that things taught should be interconnected, emerges strongly from the data. In our discussions about the curricular implications of teachers utilizing the Internet for curriculum projects, Ms. Brook established her view of curriculum as an interdisciplinary entity:

> It makes the whole idea of integrated curriculum...this puts a little more meaning to all that stuff. And it's one more thing that hopefully takes the teacher away from the idea that 'now we're teaching math, and now we're teaching science, and so on' - separating the subjects and issues...

As Ms. Brook talked further, she began to talk about how she visualized her classroom as a beginning teacher. In her professional development, Ms. Brook began to see curriculum as integrated. She stated:

> I began to learn stuff that way, so I guess in a lot of ways I made it a goal of mine that I was going to learn science. I knew I was already doing an effective job of teaching language arts, and strong in writing and literacy, and knew how to get a whole language classroom going. Then I started learning some stuff about integrated curriculum so I knew that a whole language classroom didn't just have to look like language, it could look like science, and history, and current events, and literature all together......cause then you can just integrate it (science) into all of the other subjects as well. In some ways skip a reading lesson because we're doing so much science

> that day but then they're not skipping reading they're doing the reading involved in that. All of the topics that are required of me in science for 4th grade science I've been covering continuously in the Okefenokee project, TAL Kenya, then the Kobe project....because I've been integrating it into the whole school year for these kids rather than a skill or subject in isolation......

In this passage, Ms. Brook described the interdisciplinary nature of the technology-rich curricular projects that she implemented throughout the year. The Kenya and Kobe projects she mentioned are analyzed in detail in chapter 6, and demonstrate not only the MEGOSE dimensions of scientific literacy but also the specific dimension of integrated curriculum. While MEGOSE recommends science curriculum to be designed in thematic, interdisciplinary units, it falls short of providing examples of how to accomplish such design (MDE, 1991). In describing her integration of instructional technology into her science curriculum (Okefenokee, Flamingowatch, Kobe, etc.), Ms. Brook is describing the types of projects that integrate science and instructional technology. If the use of instructional technology is necessary in pursuing scientific literacy, that is, if the ability to use instructional technology is subsumed into being scientifically literate (MDE, 1991), then Ms. Brook is pursuing, through her curriculum, a direct connection between instructional technology and scientific literacy.

Ms. Brook indicated that part of her expertise in creating interdisciplinary units is due to professional training sessions, but she also acknowledged that she had read a lot about it in professional publications and that "you kind of get it on your own..." Below, Ms. Brook talked about the "integrated" nature of the Flamingowatch project:

> Well, I guess the integrating part is.....it's more of the kind of thing that permeates everything....and I think that those Flamingowatch days certainly were along the integrated curriculum concept.....I'm not sure which model it fit, whether it was immersion, or threaded through, or whatever the phrases are, but um, there were certainly across the curriculum activities that happened..... um, then the study of the people in the area, the animal research investigating how they did it technologically to make all this happen, moving the desks into formation as if we were on an airplane, um, talking to Bob Whiteman who brought in Kenyan music so that we were employing the arts along with it, um, the kids did an awful lot of writing, and an awful lot of discussion, um, some artwork with the whole thing, as much as I could I think we just tried to immerse as much as I could of the curriculum..... and to get as many different aspects as I possibly could.

> There were discussions about food and discussions about traditions of the people of Kenya, ...are there any parts of the curriculum that we've missed so far? (chuckling) I think they're all there, aren't they! But I think it trivializes it when I say well now we're doing art, etc. I'd really rather look at it as <u>the whole picture</u>.

In this passage, Ms. Brook analyzed the different curricular topics integrated within the Flamingowatch project. Art, music, culture, as well as the geology and geography of the region were all attended to. This view of interdisciplinary curriculum corresponds to that of <u>Benchmarks</u> (AAAS, 1993). Students also utilized the instructional technology to research topics in more depth and to "make this all happen." Ms. Brook did not view the project as being divided up into the different curricular areas, but viewed it as "<u>the whole picture</u>."

Another example of how Ms. Brook views curricula as interdisciplinary was related to me in a reflective conversation we had about the events in a particular lesson. I asked whether any factors distinguished the way we think of science as a discipline, teaching science, and the outcomes we want from students. Ms. Brook responded:

> Boy I hope not! Because then it becomes an isolated skill again and ....(laughing) I should hope not. I want, as an educator, and as a person out there learning for all this science stuff to just be integrated into the real-world stuff - I don't want it as a separate entity.....it is valid to think in terms of scientific literacy, but it is not exclusive to science. OK, is it scientific literacy what you saw those kids doing yesterday being introduced to Netscape? You bet it is!! Those kids were asking "what is chaos" and another kid answered based on what he understood from Jurassic Park and he was right!?
>
> Now, if you want to look at that as science, go ahead, or if you want to look at it as language as I certainly pursued with Martha (in allowing Martha to give a long verbal description of what a food web is)......do you want to look at it as communication.....here's multiple conversations going on at the same time.......do you want to look at it as reading? That screen came up with Fun Facts and everyone was reading it.....do you want to look at it as social interaction? You know, you want to look at it as all of that at the same time. Not just science........ but yes, there sure was scientific literacy going on in that activity......

Regarding this passage, we both agreed that science educators are interested in <u>all</u> students in our society being capable of having the kinds of conversations that her students were having and that those conversations were indicative of a certain level of scientific literacy in her students. For example, Ms. Brook felt the students' learning how to navigate the World Wide Web using Netscape was a part of scientific literacy. She gave examples of the verbal interactions among students spawned by the Netscape activity. Topics such as chaos theory, food webs, and scientific "Fun Facts," all led to multiple conversations among students based on the information they were finding using Netscape.

Ms. Brook also viewed language usage as inherently important in defining scientific literacy. She stated that while there was activity occurring during the activity, the vitality of the lesson was produced in part, and sustained by the language usage, multiple conversations, reading, social interaction, and communication taking place. Thus, Ms. Brook described as important the following components of scientific literacy: using and constructing scientific knowledge (MDE, 1991).

Although Ms. Brook described one of her views on scientific literacy in this passage, she also again emphasized her holistic view of science by relating that all of the processes described above counted as science, not just the science content and technology aspects of the lesson. Thus, I emphasize that Ms. Brook created an interdisciplinary curriculum by integrating various subjects and accessing various interdisciplinary resources. This integration was created where it otherwise might be overlooked.

Assertion 3
Ms. Brook feels that good science teaching is activity-based, emphasizes science content, and integrates instructional technology.

Much of what Ms. Brook talks about in terms of her science teaching involves actively engaging students with science content, focusing on lessons that are activity-based. She sees herself as facilitating the learning process, and advocated learning right along with the children. Utilizing instructional technology plays a big role in that process. Early in the data collection process, I asked Ms. Brook to define good science teaching:

> Good science teaching? It would have to be things that are relevant to the student, activity-based, and less on book learning, interactive with their classmates, or interactive with other people, active, interactive, teaching would have to be put into terms that are easy for children to understand - you can use all of the terms that you'd find in a textbook but if that didn't

> make any sense to the kids, if it's not in a language they understand it's not going to be good teaching until you put it into words they can get. Good science teaching also has to have as many different senses employed as possible....whether it's visual, graphical organizer, a web, or something with the concepts as well as the STUFF (her emphasis) itself that you're teaching science with. The stuff that we're working with, the classmates are talking about it, listening to the story some, being able to say it, and explain what they're talking about.....all the senses.

Actively engaging students in scientific inquiry is endorsed in the science education literature (AAAS, 1990; 1993; MDE, 1991; NRC, 1996; Raizen and Michelson, 1994; and Tobin and Fraser, 1987).

In Ms. Brook's view of science teaching, students are actively engaged and interactive with others. This interactivity manifested itself in Ms. Brook's classroom almost daily due to the project-based, technology-rich curriculum. Students worked in groups more often that not, and frequently interacted with others throughout the world by utilizing the Internet.

In describing good science teaching, Ms. Brook recognized the difficulty many elementary teachers face in trying to utilize instructional technology, teach thematic, project-based science units, etc. (Ferris and Roberts, 1994; Becker, 1994). She also felt that good science teaching as she described it is very hard to do, and that relatively few elementary teachers have the skills to do it. The complexity of good science teaching and the fact that few elementary teachers are considered exemplary science teachers is described in the NSES (NRC, 1996).

On the other hand, Ms. Brook feels teachers can learn the skills necessary to teach science effectively if they put their minds to it - like she has over the years. The following passage, while it contradicts her earlier memory of her college preparation for teaching, gives a rich insight into Ms. Brook's feeling about actively engaging children in science content:

> And it's a mind set. My college methods was very fieldtrip oriented and hands - on. So, I learned how to think about how children really learn, and I am inclined towards being actively engaged with the curriculum and my training really helped me. I was taught that "you didn't just talk about music, you made music." You try to experience the curriculum and school activities rather than just read about them...... and in traditional teacher training, that's not so. I have to figure out each time when I'm teaching

> how can I bring the curriculum closer and closer and closer to the kids........

Again, Ms. Brook uses a music metaphor to relate her feelings about how children's learning is related to science teaching. It's all about "making the music" rather than reading about it.

School science curricula can be placed on a continuum from textbook-driven to teacher-driven (Glynn and Muth, 1994). In a textbook-driven curriculum, the textbook is used to support teachers who lack scientific knowledge, training, and experience. In a teacher-driven curriculum, the textbook serves primarily as a reference rather than a curriculum guide (Glynn and Muth, 1994). Ms. Brook does <u>not</u> view utilization of science textbooks as conducive to good science teaching, which is not surprising given her views about active engagement of students. This is not a devaluing of textbooks; her classroom is full of books, although there are no science basal texts. However, science textbooks do not represent the teaching paradigm that Ms. Brook utilizes.

In the traditional paradigm of science teaching, the textbook and the teacher, not necessarily in that order, are seen as the authorities of knowledge (AAAS, 1990). Ms. Brook sees herself much differently, and as such utilizes science textbooks only as references. Here's how Ms. Brook describes her role as teacher as she discusses the Flamingowatch project.

> (smiling) Sure, the kids accepted her and talked about her as Peggy (laughing)...... I guess I don't usually perceive my role as the expert....maybe I'm a gatherer of materials to help the kids learn something and certainly a facilitator to help it happen..... and sometime orchestrate it if they need that although I'd rather just sort of be in the background and guide it from behind.....

In this passage, Ms. Brook referred to herself as a "gatherer of materials," someone who facilitates classroom activity. Ms. Brook does not view herself as an authority on science knowledge, rather she prefers to "orchestrate" activity or "guide it from behind." In this view of her role as teacher, she reflects Raizen and Michelson's (1994) view that teachers are responsible for managing and monitoring student learning. The <u>NSES</u> (NRC,

1996) also use the term "orchestrate" in describing a teacher's role, saying an exemplary science teacher would "orchestrate discourse among students about scientific ideas" (p. 32).

In facilitating, Ms. Brook is very interested in students' ability to go beyond using science textbooks to being able to access, share, and utilize information. In discussing her students' ability to access information, Ms. Brook stated:

> You know if you asked this same group of kids, or just any group of 4th graders "if you wanted to find out about something, where would you look?"........I think the quick response out of a lot of kids would be "look in the encyclopedia, or the library......" Very straightforward as to how to find information.......I think if you asked my group of 4th graders the same question, they'd list a lot more sources such as "experts in the field, video, Internet, books, and encyclopedias, and, and, and,...........I think that's a pretty big difference......It doesn't matter if I'm teaching them particular details about the earthquake or whatever, they're gonna learn that stuff.........but more importantly, if I can show them how to get that information, instead of just giving them the information........I don't remember all the details about the different types of earthquakes, but I have the skill to be able to access the information and find out what I need to know in order to be prepared to teach it, or anything...................so, what would I rather teach my students, the details about different earthquakes or how to access the information themselves?? So, this whole issue of accessing information, no matter what the subject it is, is more important that the content of that subject....

Ms. Brook feels so strongly about the issue of students accessing information that she argues it is even more important than the content itself. She stated that the content of science, be it earthquakes or other topics, should not in itself be the curricular focus. Even though Ms. Brook is cognizant of her responsibility to attend to topics in the district's science curriculum, she argued that students will forget facts and details, and thus the important thing is to know how to access information. She also suggested that her students have learned to utilize a variety of resources while seeking information that most students would not consider. I infer that Ms. Brook feels her students demonstrate an unusual sophistication in their ability to use multiple resources in seeking information. Grejda and Smith (1994) argue this is a primary role of instructional technology, and that each teacher should be able to utilize computer-based technologies to access information.

As we talked further about accessing information, I shared with Ms. Brook that that was a topic I asked her students about. I pointed out that my analysis of student responses in interviews about science and technology indicated that her students were talking a lot about the importance of accessing and sharing information. Following is Ms. Brook's response.

> I think that is really significant (that kids were talking about sharing information and using multiple resources, etc.) This is the difference. A few years ago when I wasn't using technology in my teaching, kids would have just referred to a book as the authority for knowledge, or where to find information. And they couldn't find much information. But, look at what these kids said! If they said that they knew how to access information and learned different ways of accessing information, then that is very significant......

In this passage, Ms. Brook shared her view about one of the effects of using instructional technology in teaching in content areas. She viewed students' responses about the importance of sharing information as very significant and attributed it to the influence of using instructional technology.

I also related to Ms. Brook that her students had the ability to think critically about information they accessed while doing research. I shared with Ms. Brook that students had indicated to me that they understood the need to verify the information they found, regardless of the source. Ms. Brook viewed that knowledge as being "really advanced for a fourth grader." She also related that during research projects, her students frequently questioned the validity of information when they discovered sources with old copyrights.

Thus, Ms. Brook viewed good science teaching as helping students actively engage with science content, in part by utilizing a variety of resources, including instructional technology, to access information. She felt it important that students think critically about the information accessed, and share ideas and information with each other. Ms. Brook feels her students have sophisticated skills in using instructional technology to access scientific information.

Assertion 4
Through utilizing instructional technology, Ms. Brook views science curriculum as unlimited in scope.

Computer telecommunications can help teachers and students think about curriculum and classroom organization in different ways. As Internet use in classrooms expands, teachers and students will think beyond their basal texts and school libraries and begin to access the libraries of the world, government agencies, university scholars, and other students as sources of curricular information (Johnson et al., 1994). Ms. Brook and her students have already begun this process. Ms. Brook uses the metaphor that by utilizing a modem, the whole world becomes your classroom. She views students' "real world" as being anywhere they can "travel" electronically. She is careful to tie those electronic journeys to concrete experiences in students' local area of Jefferson. Ms. Brook related that she and her students were on a journey together, a journey of learning. In this section, I revisit that view with Ms. Brook by asking whether the journey of learning could occur without technology and the Internet:

> Absolutely! I want a faster journey though, and I already know how to access information from books, and from people, and that journey never ends. People are your absolutely most wonderful source of all, and yet the technology also, actually the technology is what hooks me into more and more people....... Um, and at a much faster rate. It incredibly means that I can take this journey in a much more intricate way. Because, it's one that challenges me a whole lot more. Do you see what I mean that is happening here? It's connecting with people...

Being able to take a "faster journey" by utilizing instructional technology to access information and connect with people requires a high level of technological literacy as described by Grejda and Smith (1994). Following this discussion, I asked Ms. Brook how her use of instructional technology had changed her idea of what science curriculum is or could be:

> It's been about four years that I've been trying to do this technology, and I didn't know where I wanted to go with science. I knew I had to teach it and I didn't see very much relevance to my own life. If I needed any scientific stuff, my husband would handle it for me...... I don't know if it was technology use that changed me or just my decision to learn more about science and then, once it was a commitment I made to learn more about

> science, then I guess I'd employ any piece that I could to make that happen. Again, technology is just one of the parts, even when I started with trying to teach science more effectively, it was four years ago doing a study of the body systems and I had a parent come in to talk about the muscular system and I had a program at home called Body Works, but we had no computer in the district that could run it. So, the superintendent loaned me his computer to play around with so I set it up and had this thing running for about three weeks and had every kid go through Body Works to be able to use this program but it wasn't the technology that drove the science curriculum it was my decision to teach science more effectively and, integrating as many things as I could into it has just been the way that I like to approach learning anyway.

As I talked with Ms. Brook about science curriculum and utilizing technology, I reminded her of her metaphor that the whole world is accessible to students because of the modem in the classroom. I asked Ms. Brook whether the opportunities provided by Internet use could influence how she might view science curriculum in the future?

> Sure. So isn't it awesome that it has expanded! Then this (technology) makes science study real-world learning instead of a book that was published four years ago and had information in it from ten years ago! What makes learning real?! Like Mount St. Helens, my students weren't even born, so looking at it in a book doesn't mean as much as learning something in real-time. Isn't it cool what technology gives us? Because what it gives us now, if I'm going to take advantage of it, is real-time learning. Um, then it is real, every single word. It makes learning from books a secondary thing because that's more of a history of a topic but if you want to know what is happening right now, you have to access it real-time. Isn't that the way you'd rather approach it with kids? And, isn't that a cool motivator?

These passages reveal some of the most important information I discovered about Ms. Brook. Three significant philosophical beliefs seem to frame Ms. Brook's thinking about curriculum, teaching, and learning:

1. Students' use of technology expands the classroom worldwide, providing real-world learning experiences;

2. She and her students are on a journey of learning together;

3. She views learning holistically, freely integrating other subjects into the science curriculum.

The first point is a significant departure from teachers' traditional view of curriculum being based on a static body of knowledge which is to be "transmitted" from teacher to student, primarily through using basal textbooks and didactic methods. Ms.

Brook's description of being on a journey of learning together with her students more closely approximates a constructivist view, where knowledge is not transmitted directly from teacher to student, but is "actively built up by the learner" (Driver, et al., 1994 p. 5). It is also significant because of the emphasis on "real-time" learning, that is, the learning is contemporary or happening "now." Ms. Brook is careful to comply with district curricular requirements and stated to me on many occasions that what she was doing, the Kobe project for example, dovetailed with the required fourth grade curriculum. Nor did Ms. Brook disavow the use of textbooks entirely, especially various types of supplementary reading sources. On the other hand, her vision of what curriculum can be has widened greatly through her use of instructional technology. She used the Virtual China project as a way to explain that philosophy. Rather than have students read from a reference text on China, she involved them in a technology project that brought up-to-date information into her classroom via the Internet. She did not suggest her students totally disregard the information in the book, she encouraged them to supplement that information with current, real-world information being shared by her students' academic peers in China. Thus, I would describe Ms. Brook's view of curriculum as expansive, perhaps visionary when compared with the traditional paradigm. For example, the MEGOSE view of real world contexts does not approximate Ms. Brook's global view of real world contexts (MDE, 1991). In MEGOSE, real world contexts are described as those in which students can readily interact with, such as the playground and their natural surroundings. Barring that, materials such as photographs, pictures, etc. that represent the real world to students are considered to provide the real world contexts. Compared to the MEGOSE view, Ms. Brook clearly has an expansive, technology-driven view of what real world means vis-a-vis science curriculum.

This passage also reveals Ms. Brook's specific thinking about technology and its influence on science curriculum. In a sense, Ms. Brook described her own metamorphosis from one dependent on her husband for "things scientific" to a person who has learned how to utilize instructional technology to teach science. She described the learning curve inherent in this process and acknowledged that her ability and confidence in teaching science has steadily grown.

Again, I think a significant finding of this study is uncovering Ms. Brook's view of science curriculum as being "expanded" to include world events as part of the daily fare in science class. She described it as "real-time learning." She explicitly stated that use of technology to expand learning experiences "makes learning from books a secondary thing." Below, Ms. Brook describes technology's ability to motivate children and provide authentic learning:

> So, when we talk about authentic learning, going into the Internet to find out about that stuff is gonna help me do a lot more authentic learning. We could study about weather by going out into the yard and looking at the clouds and that's how it's traditionally been done, but hey, let's go look at some weather maps and see it actually happening.

After reading this passage, I felt it was somewhat contradictory. Was Ms. Brook suggesting that finding information on the Internet was better or more authentic than direct experience with nature? Ms. Brook clarified the comment by saying that she also valued the experiential learning associated with going outside and looking at clouds. However, the value of studying weather through the Internet was that one could analyze weather maps from various parts of the world in real-time. Thus, although it would be impossible for students at Jefferson Elementary to go outside and view the weather patterns in India, that activity was possible using the Internet.

How important is the "real-time" factor in students' learning? While that is an avenue for further research, Ms. Brook definitely feels it is a crucial element and one the traditional paradigm lacks.

The second point is more implicit than explicit in this passage. When Ms. Brook speaks of being on a journey of learning, she implies she and her students are on that journey together. She specifically describes the impact instructional technology is having on her science teaching, and on her students' learning opportunities. She also specifically describes her Internet use as a way to make personal connections in devising technology-based science curriculum (Johnson et al., 1994). Her discussions of using science software in her teaching of human anatomy, which allowed her to be more effective as a science teacher, implies her beliefs about the benefit for students in being on this journey of learning with her.

Ms. Brook's views about interdisciplinary learning and integrating the curriculum so that subjects are interconnected with each other and with students' real lives have been described. In this section, Ms. Brook reiterated her view that subject integration, especially the integration of instructional technology in science teaching is critical to her view of learning. Her "journey of learning" metaphor suggests a view of learning consistent with those of science education policy documents (AAAS, 1990; 1993; MDE, 1991; and the NRC, 1996) and literature on effective teaching and learning (Berliner, 1986; Tobin and Fraser, 1987; and Raizen and Michelson, 1994).

Assertion 5
Ms. Brook has a weak professional background in science but a strong professional development experience in science education.

Ms. Brook is a literacy specialist, with no major or minor in science. Like many elementary teachers, her professional teacher preparation course left her ill-prepared for dealing with the conceptual base of science or the pedagogy involved with teaching it (NRC, 1996). Ms. Brook described her professional preparation to teach science as "zero." In reflecting on her undergraduate preparation to teach science she states:

> Oh, yeah...boy...in undergraduate school, I don't know if I ever took a methods course in teaching science. I'd have to check my transcript.

Yet, Ms. Brook not only teaches a lot of science, she does so by integrating the MEGOSE dimensions of scientific literacy into her units. She also envisions science as a part of an elementary curriculum that is essentially interdisciplinary. In the previous section, she clearly stated that science should not be viewed as a separate subject fostering unique skills. This viewpoint is another indicator of how her views of science teaching and learning are divergent from the traditional paradigm of science teaching which focuses heavily on passive, textbook-driven learning.

Thus, in at least two ways, Ms. Brook seems to be an anomaly vis-a-vis her science teaching. On the one hand, her professional preparation to teach science is limited; on the other hand, she teaches science daily. Also unusual is how Ms. Brook seems to feel about herself as a science teacher as compared to how she presents herself when she is teaching science. In describing herself as a science teacher, she openly admits her weaknesses, and sees herself as someone with a long way to go to become effective in her science teaching. But in the classroom, she confidently implements science curricula by having a firm grasp on the content, her goals, and the teaching strategies necessary to achieve her goals. In the passage below, Ms. Brook hints at how she feels about teaching science and how she has accumulated a great amount of knowledge about teaching science:

> I've known for a long time that science has been my weak link...for knowing what science concepts are. And that's a determination of mine, to try to go back and learn that stuff...
>
> GC: Through coursework?
>
> Reading, training, and stuff.

During the school year, Ms. Brook attended several workshops on science education and instructional technology. She has more than a casual familiarity with MEGOSE and has extensive training in science curriculum development focusing on teaching for conceptual understanding. This training was received by attending Science Education in Michigan Schools (SEMS) workshops through the local university in partnership with the Department of Education. I asked Ms. Brook to describe her training in the SEMS workshops, and whether the school district's goals and objectives in science education were similar to those in MEGOSE (MEGOSE is provided to teachers who participate in SEMS workshops).

> Oh absolutely, very, very closely tied to those. A lot of the science stuff we're teaching right now in this district has been written since this book came out (points to the MEGOSE book). It's good stuff and a very usable book .....It is so nice and now that I've been at it for a few years, um, it's a

> lot easier to internalize what's in the book. When we started SEMS, I think I've done SEMS three different times. No, I had it 4 times all together and I guess I really do need to hear that kind of unfamiliar stuff several times over to learn it......The SEMS trainers got a less than positive reception from many of our teachers who just want a textbook to use.......

In this passage, Ms. Brook described her confidence in MEGOSE and felt that Jefferson school district's objectives for science education were closely tied to those in MEGOSE. What is very interesting here is that Ms. Brook admits to attending the SEMS workshop four times. These workshops not only prepare teachers to teach the concepts of science, but also model the types of hands-on engagement with science content that is a necessary component of teaching for scientific literacy (NRC, 1996; Tobin and Fraser, 1987). Finally, this passage indicates that Ms. Brook has become more confident about teaching science through attending SEMS and other workshops.

Ms. Brook has taken the initiative to become better trained to teach science. Much of that training has resulted from her participation in professional development workshops. Attending frequent workshops, reading voraciously on science and technology issues, and teaching herself how to use the Internet speaks to a strong disposition to learn. How else might Ms. Brook prepare herself for not only science teaching but also her utilization of instructional technology? She has definitely not pursued more university coursework and has expressed dissatisfaction with the traditional methods found in many university courses. In trying to address these issues, I asked her why so little elementary science seemed to be taught in schools.

> Because we don't know the concepts themselves. And, relevance to real life (of the concepts)...and....don't know how to make the subject interactive with the kids, difficult to get materials together even when you do get it figured out why you should have the lessons be active. Without a really strong science background, it's really difficult for a lot of teachers to jump in and try to teach science. It's not a natural....reading is a natural to a lot of people....math can be a natural to a lot of people....social studies and writing, so many things can be a natural but science doesn't feel like a natural...
>
> As a stereotype, women throughout traditional upbringing, we're not encouraged to be very scientifically minded, or math minded....the numbers of women who teach in elementary schools is pretty great.....that whole analytical way of thinking isn't seen as typically female....Although even in

> teacher training you hope that whatever they're getting at the university, they're employing some of the latest and most effective means of delivery on how to teach...they tend to give off a lot of content and it's no different from a traditional high school setting where the teacher delivers the information and the kid is supposed to sit there and write it all down, that's not modeling good teaching..

In this passage, Ms. Brook highlighted issues concerning the difficulty of science teaching in elementary schools. First, she stated that many elementary teachers do not have strong science backgrounds and do not know the science concepts they are to teach. Thus, science teaching is "not a natural." The difficulty of science teaching described by Ms. Brook concurs with Anderson's (1989) view that good teaching is very complex and requires a "pattern of practice" that develops over many years. Next, Ms. Brook raised the issue of gender in science teaching. She stated that stereotypically, women are not encouraged to pursue science or mathematics. Tobias (1990) writes about womens' underrepresentation in science education and in the scientific community. She argues that women and minorities are not usually members of the "chosen few" who enter the scientific community when she writes:

> Unless they are unusually self-motivated, extraordinarily self-confident, virtually teacher-and curriculum-proof, indifferent to material outcomes, single-minded and single-track, in short, *unless they are younger versions of the science community itself,* many otherwise intelligent, curious, and ambitious young people have every reason to conclude there is not place for *them* in science. (p. 11)

Because of the high number of women in elementary classrooms, science teaching suffers. Finally, science teaching at the university level does not model the "good teaching" that science reform efforts call on today's teachers to do (Tobias, 1990). Ms. Brook's analysis of university courses closely parallels that in the current literature (MDE, 1991; Tobias, 1990; NRC, 1996; AAAS, 1990; 1993). Given this analysis, I asked Ms. Brook to reflect on her strengths in science teaching:

> Well, a lot more this year than other years, part of it is this is my first year in 4th grade and a new curriculum is a kick...it's fun....part of it is too 4 years ago or so I decided for myself I wasn't doing an effective job teaching

> science cause I didn't know science and so for all this time I've been pursuing learning about science...
>
> GC: When you say you didn't know science are you referring to content?
>
> Either content or how to deliver it....well, with enough preparation I could deliver it but...I didn't know enough content to feel really comfortable with teaching it so I think I thought I felt like I was teaching isolated lessons....I would prepare like crazy to teach a lesson, and then because it took so much preparation and so much learning for me, it was difficult to really have a lot of science lessons going on because it took so much time for me to learn it. It was tough. And, then I started taking stuff like the SEMS training, and reading a lot of science stuff, being a member of the Michigan Science Teachers Association and going to science conferences and then the work I did with the wetlands and stuff like that was sort of a natural progression.

As Ms. Brook succinctly puts it, many teachers just don't have the background to teach science, and therefore they don't. Ms. Brook also expresses that many university courses tend to focus on the science content, but do not model good science teaching. Thus, it is not surprising that Ms. Brook has pursued her continuing professional development at school-based and other workshop sites rather than through continued university coursework.

Ms. Brook has pursued fairly continuous professional development in science teaching and learning over the past four years. Ms. Brook views workshops in science and technology as being vital to her continued professional development, a process which will continue throughout her professional career. This philosophy is consistent with that described in the NSES:

> Becoming an effective science teacher is a continuous process that stretches from preservice experiences in undergraduate years to the end of a professional career. Science has a rapidly changing knowledge base and expanding relevance to societal issues, and teachers will need ongoing opportunities to build their understanding and ability. (NRC, 1996, p. 55-56)

She acknowledges that science teaching this year has been fun, partly because of the excitement of teaching 4th grade for the first time, and partly because the technology projects fit so neatly with her intended district curriculum. However, her realization that she needed more preparation to teach science was a conclusion that she reached consciously about four years ago. She says she came to that conclusion because she "didn't know science." Because she didn't "know science," it made teaching it too hard for her. Ms. Brook's dialogue indicated that she lacked the pedagogical content knowledge, or subject matter knowledge for teaching, described by Shulman (1986; 1987) and Wilson et al., (1987). She described having trouble with "how to deliver" science content. Buchmann (1984) argued that for teachers to teach, they must have knowledge of the content. Ms. Brook seems to agree and described the frustrations involved with trying to teach science without knowledge of "the big picture." Her active participation in professional development and professional science organizations has given Ms. Brook not only a "bigger picture" than she had, but also the confidence to continue to teach science.

Assertion 6
Ms. Brook has taken the initiative to learn about instructional technology on her own.

Because instructional technology is highly integrated into her science teaching, I examined how she gained expertise in this area. Many classroom teachers have very little practical or pedagogical knowledge in this area. After all, personal computers and most instructional technology did not appear in classrooms until Ms. Brook was years into her professional career. Still, she is highly skilled in utilizing instructional technology and views it as her curricular window to the world. How has she attained her skill and confidence in utilizing instructional technology?

Throughout this study, there is evidence to support the notion that Ms. Brook has a strong disposition to learn, and where science and instructional technology are concerned, she could be described as an inveterate learner. To learn more about her use of instructional technology, I began by asking Ms. Brook to describe how she has gained expertise and confidence in integrating instructional technology into her teaching:

> The biggest influence would probably be Don (husband)...he works with computers at work and ......well no, another big one is just that as a writer, I need technology in order to be effective at the writing. I mean the tools that we use even just for writing I had to learn a lot there....as far as, I don't know........I guess I just wanted to learn about it (tech), even just in the way of classroom management of .....in lesson design - I've got an awful lot of stuff that I do in the classroom that's on computer disk right now and

> it's an easy thing for me to go find my stuff...you know how did I teach this lesson on ....? I can go back through my word processor and find the lesson that I wrote up and I mean even just in that regard.....I mean who needs hanging files anymore if you've got your stuff on a disk? Just the ease of being able to manage that kind of stuff in the classroom, the more I learned, the easier it became to use tools like that and to produce a study sheet or worksheet for students .....and have it look like this (holds up scrappy hand-written document) compared to this (holds up neat, orderly word processed worksheet) well shoot.....I know for one thing students are going to learn more if it's neatly typed and laid out and appeals to kids.......my students are going to learn more if the presentation of their stuff that I want them to write and respond back to is in a way that they can do it. This type of stuff is probably pretty small compared to where you really want to go with technology, but it's probably one of the things going more and more in technology is when you can use tech so easily that it just is automatic, rather than planning how to use tech for certain stuff, I mean, I'm not there yet if I'm still thinking like that but if I think 'here's the stuff I want to learn with my students or here's the stuff I want my students to learn from me, what's my most effective way of presenting it?' If technology automatically becomes a part of that then.....then tech is a pretty efficient tool.

This passage indicates that Ms. Brook has been intrinsically motivated to learn about technology and was quick to see the utility of technology as a tool for planning, classroom management, and ultimately, for integration across the curriculum, uses consistent with Grejda and Smith's (1994) principles of technological literacy. In describing how she utilizes instructional technology for planning and designing lessons, Ms. Brook emphasized the idea that technology use by teachers needs to be "automatic," able to utilize the technology without thinking about it. In writing about today's paradigm shift into the information age, Viau (1994) argued "We need to make information technology both transparent and visible" (p. 10). Viau described that process this way:

> Making technology transparent means saturating our environment with it so that it is accepted as a matter of course. Our students should reach for the computer as their grandparents reached for a pen or pencil; automatically. (p. 10)

Implicit in Viau's argument is that people need to be prepared to utilize technology as their first option, as a matter of course. Students, just as most teachers, do not automatically choose instructional technology either because they do not have access to it, or more probably because they have not been adequately prepared to do so. Ms. Brook does utilize instructional technology as a matter of course, and is teaching her students to do likewise.

Ms. Brook emphasized pragmatic reasons for using instructional technology in her classroom, citing the need to streamline and economize planning and preparation by doing all lessons on the word processor. Grejda and Smith (1994) cite the need for teachers to be able to "use computers and other related technologies to support the educational process" and "demonstrate skill in using productivity tools for professional and personal use" (p. 779). These professional standards cited by Grejda and Smith are implemented by Ms. Brook on a daily basis. The lesson plans, worksheets, and activities she generates and saves to disc are attractive, well-organized, and professional looking. This is in contrast to many, if not most, elementary teachers who still produce their professional work materials including notes to parents by writing them out longhand with a pen or pencil. In that regard, the level of Ms. Brook's utilization of instructional technology is in striking contrast to most elementary teachers. Ms. Brook also indirectly described why many teachers do <u>not</u> utilize technology as she does when she said "When you can use it so easily that it is just automatic." For most teachers, using technology in any sense is far from automatic (AAAS, 1990).

The following passages explore in more detail a central component of Ms. Brook's preparation to teach in general, and specifically her preparation for learning more about and utilizing instructional technology. To begin this conversation, I asked Ms. Brook if she did a lot of professional reading:

> Yeah, oh yeah, absolutely. Um, a big bulk of my reading was throughout the summer and I'll read several long books and those things will drive me as the next year goes on. For instance, Lucy Caulkins' book on writing, the big fat one, I read it and maybe I was already employing uh, 20% of it and maybe I was really believing 80% of it and so then by reading all that stuff it was like, oh, OK, this is a philosophy I can identify with pretty closely.

Thus, Ms. Brook described using the summer months to read "several long books," which help her become more professionally prepared. I asked her what she read to help her prepare for using instructional technology:

> Wow.......um, that's a different kind of reading right now. That's a good question. I'm really so much at the beginning of all this, Greg, that it's just

> bizarre. I mean even going to that technology conference, there was so much that I didn't know I was like, wow, all these pre-packages look great, I didn't know about them.......If I would say what I was going to be reading this summer it would be an awful lot of that, but, I think the way that I'm going to be reading this summer is going to be different than, you know, curling up in a hammock with Nancy Atwell's book or something like that ....um, there's an awful lot of stuff right there in the Internet, where you can download a complete book if you choose to and I guess I wanted to go in that direction, I want to learn more about stuff like key pals and projects and I want to learn an awful lot more about how to access information so, the kind of reading that I'll do this summer will be dramatically different from what I've done before......

In this passage, Ms. Brook made an interesting distinction in <u>how</u> she reads to prepare for using instructional technology, and ultimately, how she gains expertise in using technology. She described this process as largely shifting from reading books to spending time on the Internet, learning new techniques, and learning about curricular projects and how to access information. She stated that this type of preparation will be "dramatically different from what I've done before." This passage clearly delineated the type of paradigm shift Viau (1994) described earlier. Again, Ms. Brook's description of her ongoing professional development starkly contrasts to that of many elementary teachers <u>and</u> argues for a new paradigm in professional development. Many elementary teachers prepare over the summer by purchasing new materials, planning and creating bulletin boards and the like. Ms. Brook described her preparation by reading to increase her knowledge in content areas (Atwell's book) but also by engaging in a new kind of reading; reading that is "dramatically different from what I've done before." In essence, Ms. Brook is describing a process which revolutionizes her approach to professional development. It will be a personal experience in which she will continue to teach herself how to use the Internet by spending time <u>using the Internet</u>. The emphasis here is on the active-engagement with the technologies that she wants to learn about in order to implement them in the classroom. Davis (1994) described the advantages of preparation for Internet use by stating:

> The spread and potential immediacy of information regardless of distance are an important motivator and provide participants with an audience which improves relevance of the work, access to resources, and self esteem (p. 644).

I feel this distinction is important as it speaks to the process teachers might need to pursue in order to expand their own expertise in utilizing instructional technology. I asked Ms. Brook to elaborate on how this process is different from how she has developed professionally in the past:

> It's a double purpose, which is different from say the reading I did on setting up a writer's workshop, for example, you know with the Caulkins stuff and the Atwell stuff, that was stuff I already believed and I already knew the value of. Because I'm a writer I also knew about ways to be an efficient writer and I already had a fair amount of content already and skills already in that area. I've also done a lot of practicing with this kind of stuff with my students, so when I was reading those books, what it did was confirmed and validated a lot of the things I was already doing. For all the stuff I'm trying to learn with science and with technology, I don't have a real strong content base, I don't have the experience with that already ....
>
> I don't have the experience in this technology yet, I feel like I need the experience more than I need to read text on it. For instance, a book that I would choose instead of *The Whole World Internet* or something like that would be *The Internet Yellow Pages* - I heard this was really kinda cool and it has a zillion sources in it.....that's what I want to do. I need to practice what I'm trying to do, because I don't know how to do it enough yet.

In these passages, Ms. Brook contrasts her traditional preparation for teaching (reading Caulkins and other subject-area texts) with her preparation for learning more about and implementing instructional technology. She reveals that her preparation to use technology is "different" and that she is a relative newcomer to its use. In fact, Ms. Brook described her current professional reading (summer reading) about technology as being "dramatically different." She made a significant distinction about how reading to prepare for technology use differs from her traditional reading for content-area preparation. Essentially, Ms. Brook suggested that most of her technology reading would not be from books <u>about</u> the Internet, but from the Internet itself. This would allow her to accomplish two goals simultaneously:

1. Read about content and technology-related items;
2. Gain experience "cruising" the Internet.

Both are important to Ms. Brook, especially the experiencing of the Internet as she indicated by saying:

> I need to practice what I'm trying to do because I don't know how to do it enough yet.

In this section, Ms. Brook demonstrated her strong disposition toward learning about and how to integrate instructional technology across the curriculum. In Chapter 6, I describe in detail three types of technology projects that Ms. Brook and her students completed. However, as Becker (1994) argued, technology-using teachers tend to differ from other teachers. Even though Ms. Brook is an inveterate learner, she also faces impediments to utilizing instructional technology. Below I briefly describe some of the problems Ms. Brook faced in utilizing instructional technology in her classroom.

Impediments to Using Instructional Technology

Educators in all 2,000 of Virginia's public schools have Internet access. All K-12 teachers, individual students in grades 6-12, and K-5 clases, have free Internet accounts (Mason, 1994). However, many elementary teachers in other school systems lack access to instructional technology, and consequently do not integrate it into their teaching (Davis, 1994). Access must be easy, preferably in the teacher's classroom, and training and support must accompany the technology. Telephone lines must be accessible in the classroom for the teacher and students, and in order to maximize learning, students should have access to the modem and other technologies even if their teacher is not immediately present. Without these conditions being present, many teachers do not address the impediments to using instructional technology (Davis, 1994). Why would Ms. Brook expend the extra time and energy on implementing technology projects in the first place? Ms. Brook utilized instructional technology in almost every aspect of her professional and personal life. She described the technology as being only a tool, yet it was clearly a tool that had become not only motivational but also indispensible to her. Utilizing the Internet to reach out to and learn about people worldwide, and to assist her students in doing so drives her thinking about curriculum. However, as Cuban (1993) argued, there are serious limitations to teachers' uses of instructional technology, one of the most important being access to it. I asked Ms. Brook to address one problematic aspect of instructional technology, that is, the issue of unequal access to it in Jefferson elementary. She immediately acknowledged the importance of having a modem in the classroom, inferring that a computer on its own would greatly limit how she could utilize instructional technology in her teaching.

> If you have 1 computer and a modem hook up, and you had dedicated phone lines ....then all you need is 1 computer, in that regard. You just send a couple of kids off to find out about things.....you hear about an earthquake in Japan and you go into the computer and find out about it. Or if you have a CD-ROM drive and some software and you want to find out about hippos, you can go and find out. If it's just a computer with limited software, I can see where a teacher wouldn't be able to effectively use it....On the other hand, look at what those kids were able to do with the modem yesterday. Did you hear them comparing the life span of the lion and then clarifying each other's responses? Gosh.......you might as well just get rid of the old Apple IIe cause it's just a game and if a teacher had some good equipment available to them to really go in there and just go exploring.....
>
> GC: Some people would respond to that statement by saying I agree with you, but I don't have a phone line in the classroom and I'm not going to have......
>
> That's right, I know. I know that I'm really fortunate to have that, I'm really lucky! I'm making the most of it too, but the reality is that teachers don't have this stuff available to them, or you know what else the reality is too....when Frank and I went and gave a speech up in Grotto County, there were a whole mess of teachers in the room and we were talking about AOL, TAL, electronic fieldtrips, all this cool stuff....and these teachers were raising their hands saying "we don't have a local phone number to call into any commercial network." I mean, those areas are literally cut off entirely.....

In this passage, Ms. Brook is simultaneously enthusiastic about instructional technology's role in the classroom and realistic, if not slightly pessimistic about the long-term chances of its further integration into more elementary classrooms. Ms. Brook confronts the "reality" of widespread use of instructional technology when she stated: "the reality is that teachers don't have this stuff available to them....." Ms. Brook realizes that she is fortunate to have a simple piece of technology in her classroom that has allowed her the freedom to explore curriculum as she chooses, in real-time. That piece of equipment is a single dedicated telephone line, facilitating the use of one modem. Ms. Brook and Mr. Santo were each provided a phone line in their classrooms after being awarded a technology grant from a local corporation.

I pointed out that she and Mr. Santo were the only two teachers at Jefferson who had access to a modem for instructional purposes. In pursuing the equity issue, I discussed with her Cuban's vision of schools lacking the "critical mass" of technology necessary to make technology a significant player in the reform process. I mentioned again that in a sense, Jefferson elementary typified the scenario where a small pocket of excellence had emerged vis-a-vis technology use, but that most teachers in the school didn't have access to the equipment necessary for them to utilize technology to a greater degree. Ms. Brook reacted by stating:

> That's right..yes, ...and I can see why teachers without the mass wouldn't even bother pursuing any of this......they know that administration will not buy them the equipment or give them a phone line.......it would cost thousands of dollars! I think teachers are there who can do this stuff, but I don't think districts are going to put the money into making that happen......it is slowwww......Lincoln has phone lines in the classrooms, but no equipment.....Johnson school has phone lines and equipment but they won't train their teachers to make it happen........ (laughs in frustration)......I imagine a lot of teachers are for the technology but are just waiting for the district to adopt it because otherwise, it is beating your head against a brick wall.....which is EXACTLY (her emphasis) what Frank and I are doing sometimes.....and I've heard teachers say the same thing, that when the district wants it, we'll get it....

Thus, in thinking about the state of technology in Jefferson elementary, Ms. Brook realizes that equity is an important issue relating to the distribution of technology within the school, and who has access to it. Again, it is the phone line and modem that she views as critical in utilizing instructional technology because the modem is the electronic window to the world. She discussed the frustration of working in a system that does not provide the level of support necessary for all teachers to utilize more technology when she said that many teachers would like to use more technology, but are waiting for school district support.

I then asked Ms. Brook to describe her motivation for doing Internet-type projects, how she saw them relating to science teaching and learning, and how such projects benefit the students. Ms. Brook replied:

> The ones that I'll pick out to use are ones that have to do for one thing with ANY interesting geography. OK, China sure was, certainly Kenya has been, Alaska, cool geography for one thing. Then it's anything that is directly related to what I have in the science curriculum already - um, Kobe obviously with the earthquake, you know with Kobe, the greater thing was.......that the personal connection.....I mean it was like a hundred times greater, but the fact that I teach earthquakes in 4th grade, it was a natural......

In this passage, Ms. Brook described the types of Internet projects that fit into her district curriculum and her criteria for doing certain types of projects. She highlighted the Kenya (Flamingowatch), Virtual China, and Alaska (Iditarod) projects because of the close ties to geography instruction. Geography instruction was a core part of the fourth grade curriculum. She also described the Kobe project as being "a natural" because it tied so closely to the earthquakes requirement in the district's science curriculum.

Given that many of the Internet projects revolve around current events, and rely on collaboration with other schools and students, I asked Ms. Brook if she had attempted any Internet projects that had proven unsuccessful. She replied:

> Oh yeah, sure. We sent some email to the Netherlands and they didn't write back, and Peru (we both laugh).....talk about a dud! And that teaches me something for next year: I'm not going to promise anything (to the class) until I'm in the thick of making it happen cause I was saying to the kids in the beginning that we're going to be talking to kids in Peru and it didn't happen...........Yeah, so there's duds, man! I'm sure there've been plenty of duds all the way along. But, you get past those and get on to the next one.......

As this passage indicates, not all Internet projects are successful. Some, such as the Peru project, are total failures. Still, the interesting thing about this passage is that it indicates Ms. Brook has gone through a learning process related to such projects. She indicated that because students get very motivated about communicating with students across the world, it is disappointing to them when projects don't work out. Thus, much work needs to be done in organizing these projects before students actually begin to participate, thus minimizing the chance of the project's failure.

The other interesting part of this passage is Ms. Brook's willingness to continue pursuing Internet projects even though some of them have failed. Her willingness to "get on to the next one" is a characteristic that distinguishes her as an exemplary technology-using educator. She is sometimes disappointed when technology projects do not flourish as expected, but she is not dissuaded from continuing to implement instructional technology in pursuing scientific literacy with her students. This "willingness to get on to the next one" illustrates a trait that Becker (1994) identified in exemplary technology-using teachers. According to Becker (1994), "exemplary technology-using teachers spend more than twice as many hours personally working on computers at school as did other computer-using teachers" (p. 9). The 'time factor' would seem to be very important as Ms. Brook has established that she spends long hours in the summer improving her Internet skills, and she implements what she learned by spending much time at the computer in her classroom. My observations indicate that her computer time in the classroom was often spent working both alone and with students on an almost daily basis. Thus, Ms. Brook is willing to approach difficult technology projects by spending more time at the computer in order to become more skillful. However, this time investment is not a guarantee against the failure of some projects, as the Peru project indicates, because of factors out of the teacher's control.

This 'time factor' also seems relevant as Sheingold and Hadley (1990) and Dwyer et al. (1991) concluded in their studies that teachers' expertise in computer use takes about five years to develop. As Ms. Brook described earlier, she was into her fourth year of intensively focusing on improving her science teaching and use of instructional technology.

Ms. Brook evidently has a strong commitment to continuing to use Internet projects. She described the project-oriented technology projects as being "an experiment." A big part of that experiment appears to be finding the time to integrate the projects into existing curricula and taking the time to set up the hardware and software necessary for project implementation. I asked Ms. Brook how she found time to implement projects such as Virtual China:

> Yeah, look when I did them, during one of my planning times on Tuesday, but did I have any planning time? No. We set it up while the kids were right there and you were helping, I mean you just put it in and there really isn't a lot of time, you are definitely flying by the seat of your pants and that's it.......and you just fit it in and then something else gets dumped because of it........like now, I didn't want to dump this poetry project because we're going to share it with high school kids in Illinois who are going to share their poetry with these kids and I'm already about a month late with that one but, you know, I can't do it, so........it all does...........you know I love thinking about it (curriculum and how it all gets done).

In this passage, Ms. Brook indicated her enjoyment of thinking about curriculum and indicated her high degree of curricular and planning flexibility when it comes to integrating Internet projects into the curricula. She lamented her lack of time to plan and set up for technology projects and stated that "you just fit it in." <u>How</u> to fit it in seems to be an issue Ms. Brook continues to struggle with. One advantage she has is that other than her personal laptop computer, all the hardware is permanently located in her classroom. As the passage above indicates, she makes many choices about how and when to shift curricular foci in order to utilize technology projects. Some units get postponed in order to capitalize on real-time technology projects.

Other reasons Ms. Brook seems able (and willing) to overcome obstacles to utilizing instructional technology relate to her personal qualities. Although Ms. Brook stated that all she really required to use technology was a computer and a modem, other exemplary technology-using teachers report problems with not having enough computers or space to put them, out-of-date hardware and software, and having to spend time on hardware maintenance (Becker, 1994). Given that Ms. Brook utilized a maximum of three computers in her classroom, these issues were nullified to an extent. Ms. Brook often expressed frustration with the online services such as America Online (AOL), but I never once heard her actually complain about the technology available to her.

Another personal quality of Ms. Brook's has already been described partially and that is her large amount of personal initiative in overcoming fears about technology and teaching herself how to use it. Ferris and Roberts (1994) argued that one universal obstacle to the spread of technology is teachers' fear of and ignorance about technology. With the help of her husband, by attending many science and technology conferences, and because of her "risk-taking" nature, Ms. Brook has overcome any initial fears and has become an exemplary technology-using teacher.

Previous analysis revealed that Internet projects in Ms. Brook's classroom have run the gamut from extremely successful (Flamingowatch) to total failures (Peru). The Iditarod project seemed to fall somewhere in between on that continuum. From my perspective, Iditarod was very interesting and brought many different resources to bear on Ms. Brook's geography/science/literacy unit. Although the Internet allowed Ms. Brook's class to learn about Iditarod events in real-time, reading Black Star Bright Dawn and utilizing National Geographic feature articles on Alaska also contributed strongly to the project. I asked Ms. Brook to relate her feelings about Iditarod and how she rated the success of the project:

> I was real interested but I couldn't get it done! I knew a little bit of stuff about the Iditarod just having ....(we're examining the downloaded messages)........We got messages from people in Grayling, Alaska, um, about two or three weeks ahead of time I started searching the Internet for information about Iditarod and found a whole picture file of some, a whole chunk of information from a middle school in Ohio but this was last year's stuff.......so I thought well maybe the school will be doing it again so I did get started with students...and we read Black Star Bright Dawn by Scott Odell which is a WONDERFUL (her emphasis) story about an Eskimo girl who ran the Iditarod and so I just went piece by piece and in the midst of all this I had the state science conference, and that reading conference, and that technology conference so I never got a chance to finish the book.....the substitute teacher finished it.......and the kids did some maps of it, they followed the race and I have this National Geographic map up on the wall and they ....but then they didn't follow day by day because we couldn't get daily information and there was some guy, Mike McGrath in Alaska who said he'd channel information for people who wanted it but then I sent him the message I wanted to be on the mailing and he sent back and said that he was just inundated with requests for information, which was fine, it wouldn't have been cool if he would've known how to send it all out to everyone at once.....to KidSphere or KidProj .....but maybe he didn't have the ability to do that and that's how it goes......but you know, another year and that's going to be much smoother, you know, this year, this year I was

a lot closer to following something like Iditarod that I was in other years and that's OK............

This passage revealed much about the project itself and Ms. Brook's feelings about Iditarod's success. Ms. Brook indicated she could not finish the project as she was accustomed to doing. Although professing to be very interested in the project, she described a "life gets in the way" reason why the project did not live up to its potential.

Ms. Brook began the project by downloading messages about the current and previous Iditarod. She further prepared by searching the Internet for all the information she could find, which included messages from people in Grayling, Alaska. She then began the Scott Odell book with the class, the content of which focused on a young Eskimo girl's experience with the Iditarod. But in the midst of implementing this interdisciplinary unit, Ms. Brook attended three conferences: science, reading, and technology. In her absence, a substitute teacher finished the book with the class, and Internet use declined. Also, due to an Internet overload, the contact person in Grayling stopped sending daily Internet messages. Thus, the Internet connection to the project also declined. Due to this combination of factors, the project rather "fizzled out."

However, the passage again revealed Ms. Brook's optimism about doing future Iditarod projects by saying that next year it would be "much smoother." She also assessed her own progress as a technology-using educator by saying that this year she was much more likely to have attempted an Iditarod project than she was in the previous year. Thus, even though the Iditarod project was not implemented smoothly, it contained activities that formed a springboard for future Internet projects, and did not diminish Ms. Brook's enthusiasm for doing another one.

In the above analysis, Ms. Brook explained why and how she utilized projects found on KidSphere, KIDPROJ, and other listserves on the Internet. Much of her explanation is philosophical, and ties closely with earlier analysis on her knowledge, values, and beliefs about teaching and learning. By being explicit about successes and failures in Internet projects, it appears that Ms. Brook intends to continue refining her abilities at using the Internet with her students.

Summary of Findings

This section described Ms. Brook's knowledge, values, and beliefs about teaching and learning. Much of her philosophy was expressed through her discussion of how she viewed science curriculum, and how her views on science curriculum were framed by her belief in utilizing instructional technology. Although these findings are reported in this section, they reflect themes that emerged at various places in the study.

In Ms. Brook's view, teaching and learning science must provide a real-world connection to students' lives. Although there are varied descriptions of what 'real-world' means (MDE, 1991; NRC, 1996), Ms. Brook viewed real-world as observable phenomena that lie on a continuum from the classroom and school grounds, to the global community of peers and experiences available through the Internet.

Ms. Brook's conception of science curriculum is one that is connected to students' real lives, and is interdisciplinary, integrating several subjects together (AAAS, 1993). In her classroom, the primary conduit to this subject integration is instructional technology. This approach to teaching and learning broadens the scope of science curriculum to include foci on science content, scientific inquiry, social issues situated in the technology episodes, and an emphasis on students becoming "responsible citizens" through studying science. Her emphasis on the social nature of scientific inquiry is advocated in the current science education literature (MDE, 1991; NRC, 1996; AAAS, 1990; 1993).

In defining good science teaching, Ms. Brook described the importance of an activity-based science program, one that focused on science content, and integrated instructional technology. Activity-based does not only refer to hands-on science, but also refers to students interacting with the teacher and each other in discussing scientific concepts. This interactive approach to teaching and learning was evident in Ms. Brook's classroom and emerges in the chapter 6 analysis.

Ms. Brook reiterated how she viewed her role as teacher (see chapter 5) by again using a music metaphor. She "orchestrates" the teaching and learning, helping guide students, and facilitating classroom activities (Raizen and Michelson, 1994; Viau, 1994). As a facilitator of learning, Ms. Brook emphasized her role in teaching students how to access information using traditional resources, but particularly using the Internet and other technologies. In fact, teaching students how to access information in order to do research or pursue scientific inquiry seemed central to her philosophy of teaching and learning. She was not interested in teaching facts in isolation or details by transmission. As Viau (1994) stated:

> A jug can only dispense what it contains - a channel is open to a flow, a *flow-through*. The minds of tomorrow must be open, able to deal with information that changes and grows. (p. 10)

This passage summarizes nicely Ms. Brook's view that students' ability to learn, and be able to use their knowledge, requires the ability to access information from multiple sources. Studying science content from textbooks alone will not develop that ability.

Along with accessing information, Ms. Brook felt that <u>sharing</u> information in the process of scientific inquiry was vital to students' learning. Ms. Brook emphasized the significance of students talking about concepts and sharing ideas with one another. This finding is consistent with the literature's focus on student collaboration and using, constructing, and reflecting on scientific knowledge (MDE, 1991). Accessing, sharing, and verifying the validity of information are all necessary components of teaching and learning in Ms. Brook's view.

Ms. Brook's view that science curriculum was unlimited in scope is relevant to my analysis in chapter 7. By "unlimited," Ms. Brook described a global perspective vis-a-vis science curriculum. Where one teacher might show slides of the Great Rift Valley, Ms. Brook would facilitate her students talking to real people living in the Great Rift Valley. Where possible, those conversations would occur in real-time. Thus, Ms. Brook's students would have access to information that was current, provided the perspective of people in the area of study, and according to Ms. Brook, was very motivating for students to receive.

Using the Internet to expand science curricula is, I believe, a significant finding. According to the NSES (NRC, 1996), most teachers today would be scientifically illiterate when measured by the standards in the NSES. As my analysis in chapter 7 indicates, I believe Ms. Brook has leap-frogged even beyond the portrait of scientific literacy described in the NSES or MEGOSE due in large part to her vision of an expanded science curriculum, and her use of instructional technology to promote a more meaningful level of scientific literacy for students. In describing the power of contemporary instructional technology, Ms. Brook made a statement that differentiates her from most of her elementary colleagues when she says about technology:

> Because what it gives us now, if I'm going to take advantage of it, is real-time learning.

The key here is that Ms. Brook is taking advantage of the capability of the instructional technologies available to her, whereas most elementary teachers have not made the paradigm shift to the information age (Viau, 1994).

Ms. Brook's global perspective of science curricula and her flexibility in planning are manifested through technology projects that are newsworthy current events, and are linked to the school district's science curriculum. The Kobe Project was typical of a project that was developed because it was currently in the news, and corresponded to the school district's requirements for fourth grade science. The Kobe Project "covered" topics such as earthquakes and the related forces and earth-building motion associated with earthquakes (see full description below in chapter 6).

Ms. Brook's educational background and her personal qualities have played key roles in her development as an exemplary science teacher. She was able to overcome poor undergraduate professional preparation to teach science, and develop the skills necessary to learn about and integrate instructional technology into her teaching because of her personal qualities. Ms. Brook is an inveterate learner with a strong disposition to learn new concepts and apply new skills. She views learning as a lifelong process, both for herself and her students. She has become a better science teacher because she identified that as one of her weaknesses as a teacher, one she wanted to improve upon. She has, in effect, created her own course of professional development to improve her science teaching ability. This professional development has included her participation in four SEMS workshops, and many other science workshops both statewide and nationwide.

In describing her preparation to use the Internet and become more professionally adept at it, Ms. Brook described the importance of using the Internet to learn more about how it works and how she can harness the information on it for implementation in her classroom. In other words, she described "cruising the Internet" as having more utility than reading about it. This type of professional preparation she described as "dramatically different" from what she had done before. However, she described her emerging expertise in science teaching as inextricably linked to her desire to learn about how to integrate instructional technology into her teaching. Those teachers who have chosen a similar path know that this can be a humbling experience (Dwyer et al., 1990). Nevertheless, Ms. Brook is a risk-taker, one who has spent long hours at home and at school in learning how to utilize instructional technology. Consequently, she views instructional technology as the primary tool which has allowed her to expand her "journey of learning" and make the journey "faster."

Risk-taking means dealing with occasional failures. When working with instructional technology curricular projects, there is no safety net. In utilizing instructional technology on a daily basis, Ms. Brook has experienced her share of impediments to its use, and projects that have "gone South." However, Ms. Brook views failed projects as learning experiences that increase her knowledge of instructional technology and improve the probability of future projects' success.

CHAPTER 6

TEACHER KNOWLEDGE, VALUES, AND BELIEFS ABOUT INSTRUCTIONAL TECHNOLOGY

Research question 4:
What do "technology-rich" instructional units look like?

Research question 5:
What teaching strategies did this elementary teacher employ when utilizing instructional technology?

Research question 6:
How did this elementary teacher incorporate instructional technology into new or existing science curricula?

Relevant Data, Analysis, and Interpretation

> The potential of electronic communication is related to its potential audience: it is worldwide. Where students are given access, they can ignore the walls of the classroom and make direct contact with others across the world for collaborative work and in doing so appreciate the differences in culture and yet the similarity of people (Davis, 1994, p. 643).

This passage is uncanny in the accuracy with which it simultaneously describes the educational power of instructional technology and the ways in which Ms. Brook and her students utilized it in their scientific inquiries. Instructional technologies currently available to teachers and students offer significant potential for supporting active learning and adventurous teaching (Sheingold, 1990). Ms. Brook utilized instructional technology as a tool to facilitate her short and long-term planning, and in communicating with colleagues, students, and parents. Instructional technology resources also provided tools for implementing a science curriculum in which students utilized instructional technology to actively engage in science learning. In telling the story of this technology-rich learning experience, the study takes a descriptive and analytic approach. Rich description will be used to describe the technology episodes implemented in the classroom. These technology episodes are curricular examples of how instructional technology might be used in the classroom. Analysis will link these technology episodes to the dimensions of scientific literacy that frame this study (MDE, 1991).

The Flamingowatch project was central to this analysis but my intent was to contrast different types of technology episodes. While the assertions illustrated themes emerging from the data, the description of different technology episodes highlighted how instructional technology was used in different ways. For example, Flamingowatch represented a technology-rich curriculum that was organized in great detail for the teacher. Its implementation was organized around a series of live TV broadcasts and an extensive curriculum guide. In contrast, the Kobe project stemmed largely from current events, and provided students an immediate and very real-world context in which to utilize instructional technology. Finally, the Iditarod project occurred in response to Ms. Brook's attempts to supplement the science curriculum by monitoring planned events through utilizing instructional technology. Because the Iditarod is a yearly event, Ms. Brook had included it in her plans for a technology unit. These types of projects typically utilized the Internet as the primary source of information and engagement.

The three technology episodes I describe here have important differences that influenced Ms. Brook's planning and utilization of them. Because Flamingowatch was a long, comprehensive curriculum unit, it was necessary for Ms. Brook to devote a larger chunk of teaching time to it. As my analysis indicates, Ms. Brook made a conscious decision, along with Mr. Santo and their colleagues at Lincoln School, to devote about six weeks to the Flamingowatch project. The extensiveness of the unit, in Ms. Brook's view, required that she integrate many of the Flamingowatch activities into other curricular areas, thus enabling her to utilize instructional technology and attend to teaching objectives in other curricular areas.

The Kobe project, on the other hand, was a comparatively short unit. When her students suggested pursuing the issues emergent from the Kobe earthquake, Ms. Brook was faced with two pedagogical decisions: 1) whether to pursue students' interests; and if yes, 2) how long to spend on the unit. Ms. Brook highly valued students' imput into curricular decisions, and therefore decided to pursue the Kobe project with the class. Because the content focus of Kobe dovetailed with Flamingowatch students often worked on these projects simulataneously.

As described, Iditarod represented a supplemental-type of unit. Because there are hundreds of similar Internet-type projects available during the school year, teachers must deliberately pick and choose which ones to utilize. Ms. Brook was very deliberate in choosing the number and types of technology episodes to integrate into her curriculum. She valued the Turner Active Learning projects such as Flamingowatch because of their thematic, interdisciplinary nature. However, projects such as Kobe and Iditarod require the teacher to be much more of an opportunist because one cannot necessarily plan for them. Ms. Brook carefully analyzed each technology episode opportunity and made deliberate decisions on whether a particular technology episode could or should be integrated into her curriculum.

Technology Episode 1
Flamingowatch: Natural History in the Rift Valley of East Africa

A curriculum is the way teachers organize and present content in the classroom (NRC, 1996). Organized curriculum is usually represented in a curriculum guide. Curriculum guides usually offer suggestions on the structure, organization, balance, and presentation of content (NRC, 1996). Much school science curriculum is organized around science content presented in textbooks and their accompanying curriculum guides. However, curriculum can be organized in many different ways including discipline-specific (e.g., biology), or thematic and interdisciplinary (NRC, 1996; Roberts and Kellough, 1996). Walker (1990) identified five concepts of curriculum and Marzano (1992) described curriculum which focused on different dimensions of learning. Thus, there are many different ways to conceptualize curriculum. This section begins with a document analysis of the Flamingowatch curriculum guide and an overview of the project.

Flamingowatch was an "electronic fieldtrip" in which students from four local classrooms traveled to the Kenyan savanna in East Africa. For three consecutive days, students viewed an interactive telecast which was broadcast live from Kenya. Following is a description of the technology and science subject matter focus of the project provided in a faxed memo to schools throughout the viewing region:

> Delivered to the classroom via XYZ Cablevision[1], and produced by Turner Adventure Learning, this new electronic fieldtrip, FLAMINGOWATCH: NATURAL HISTORY IN THE RIFT VALLEY OF EAST AFRICA, transports the students of Ms. Brook, Mr. Santo, and two other classrooms to a region where geologic and climatic forces combine to create an environment singularly hostile to life, yet breathtaking in its biodiversity.
>
> Using two-way interactive cable, fax, and computer modems, students will be able to communicate from their classrooms with historians, scientists, and other students locally and around the country to ask questions and share opinions about Kenya and the annual convergence of three million flamingos in Kenya's Great Rift Valley. In this way, the teachers and Turner Adventure Learning combine a live event with interactive publishing, voice and video interconnects, and a variety of teaching tools that take learning behind the four walls of a classroom.
>
> XYZ Cablevision
> January 30, 1995

During these three days, students learned about the people of Kenya, the geology, and the flora and fauna of Kenya, paying specific attention to the Great Rift Valley. The fieldtrip broadcasts were hosted by Peggy Knapp of Turner Adventure Learning (a department of Turner Broadcasting), and included presentations by and interactions with CNN correspondents and local Kenya experts. Two features separate the electronic fieldtrips from typical use of video programs by schools:

1. the broadcasts were live, in real-time;
2. the broadcasts were interactive - students from schools across the world interacted with the program's experts in the field in Kenya, as well as with each other.

These unique features situated the learning experience for thousands of school children in a real-world context. To support teachers and students on the electronic fieldtrips, Turner Adventure Learning (TAL) provided an extensive curriculum guide which was organized

[1]XYZ Cablevision is a pseudonym.

thematically, integrating science curricula with mathematics, geography, literacy, and art.

1. XYZ Cablevision is a pseudonym.

The curriculum guide was organized in this way:

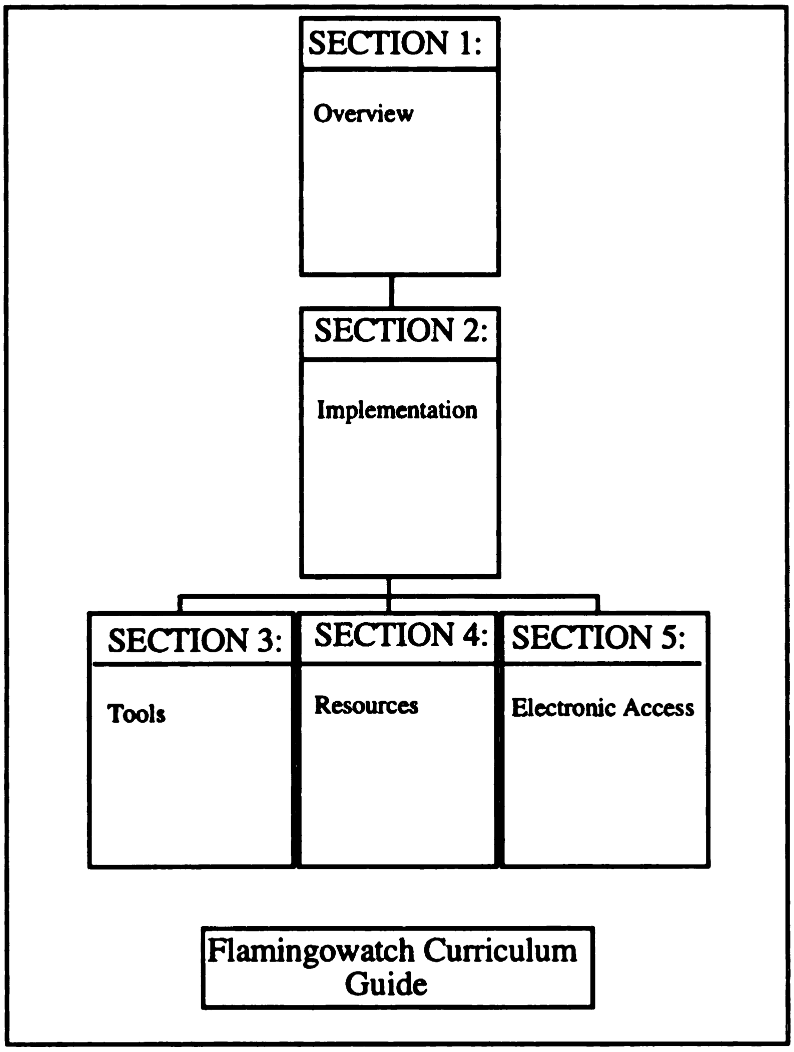


Figure 3 Flamingowatch Curriculum Guide

The curriculum guide was supplemented with a series of CNN video clips, and a text and graphics library is available on disk and on-line. The interactive portion of the fieldtrip occured in two forms:

1. students had the opportunity to interact with Peggy Knapp and the experts in Kenya in real-time;

2. students throughout the world interacted with each other after each broadcast through an electronic forum on America On-line (AOL).

An innovative feature of Flamingowatch was the extensive electronic resources provided students and teachers on Africa's Great Rift Valley. As stated, the resource library was available either on-line or on data disks that came with the curriculum guide. The resource library included a wealth of information on:

•the history of the Rift Valley;
•scientific data on the Rift Valley;
•glossary of new terms;
•graphics library of flora & fauna;
•bibliographies of film, literature, and music;
•political issues of the Rift Valley.

The implementation of the Flamingowatch electronic fieldtrip was complex, requiring much organization of different resources. The resources that supported teachers' planning and organization, as well as provided background information on the subject matter in the curriculum, were the CNN video clips, which focused on the fieldtrip's major curricular themes; a monthly newsletter, which contained updates to all on-line resource material; and a teacher training tape, which oriented teachers to the teaching strategies and resource materials created for Flamingowatch. Highlights of the training tape included:

•overall themes and objectives;
•problem-centered and content-centered teaching strategies;
•the three-day fieldtrip;
•AOL, Internet, and data disk usage;
•technical information;
•evaluation strategies;
•helpful hints from teachers experienced with TAL projects.

This study examined how Ms. Brook utilized the extensive resources provided by TAL in the implementation of the project.

The Fieldtrips

One way to represent science curriculum is to integrate the different sciences together (MDE, 1991). Another way to represent science curriculum is to integrate science with other subjects (NRC, 1996; Roberts and Kellough, 1996). The Flamingowatch curriculum was interdisciplinary, and organized around the following themes: constancy and change, observation and inquiry, and the independence and interdependence of communities. Each day of the three-day fieldtrip consisted of a one-hour live broadcast from Kenya. The broadcasts served a dual purpose: presenting information related to the curricular themes, and real-time question and answer sessions in which students used school telephones to call in questions to the host, Peggy Knapp. Ms. Knapp answered some of the students' questions and referred some questions to Kenya residents and experts. Other questions were directed to CNN correspondents in the field. Following is a brief analysis of the curricular content and subject matter of each fieldtrip.

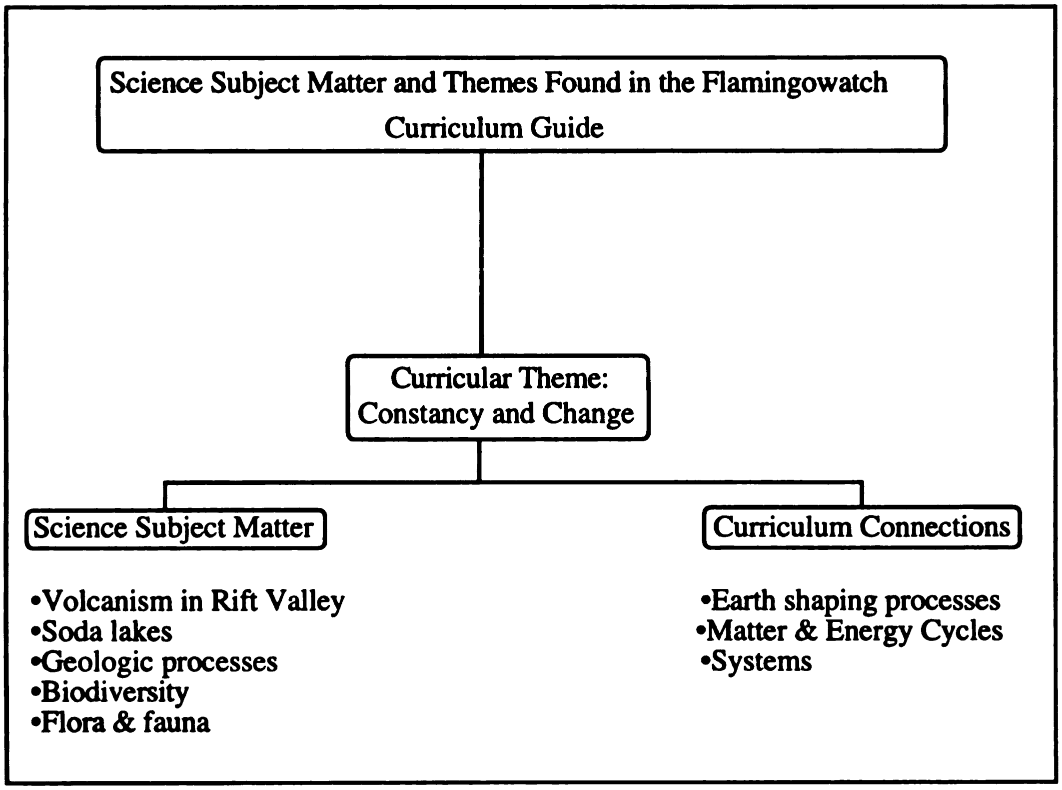


Figure 4 Fieldtrip Day 1: Constancy and Change

On day one, students explored the geology of the Great Rift Valley, the rich biodiversity found in varying habitats, and how species respond and adapt to a very hostile physical environment. The larger concept of constancy and change was emphasized. In focusing on the physical setting and the living environment, students learn that:

> The inhabitants of the soda lakes often live quite literally on the edge. Through drought and flood, tectonic upheaval, and animal and human migrations, the historic ebb and flow of communities within the area presents a fascinating picture of the balancing act that accounts for the survival of a wide variety of species as they respond to this ever-changing environment.
>
> Flamingowatch Curriculum Guide

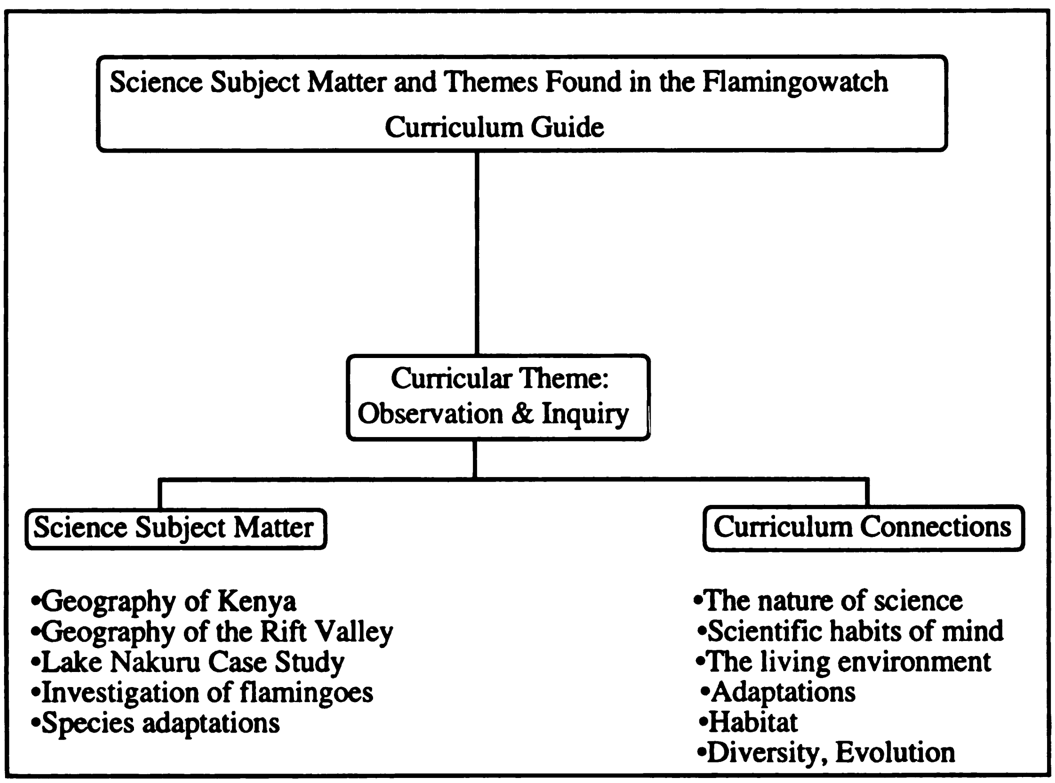


Figure 5 Fieldtrip Day 2: Observation and Inquiry

On day two, students focused on the geography of Kenya and the Great Rift Valley. The flamingos of Lake Nakuru were used as a case study of species' adaptations to harsh physical environments. Students also learned about the soda lakes of the Great Rift Valley, examined the culture of the Masai people, pastoral nomads of East Africa, and explored the impact of "ecotourism" on the environment. The theme of observation and inquiry allowed students to ponder the many mysteries that surround the flamingo population of the Great Rift Valley.

> Why do these colonies of birds migrate from lake to lake and even sometimes from Africa to Europe? What governs the 'decision' to nest and produce young? Why are they pink and how does this adaptation influence their survival?
>
> Flamingowatch Curriculum Guide

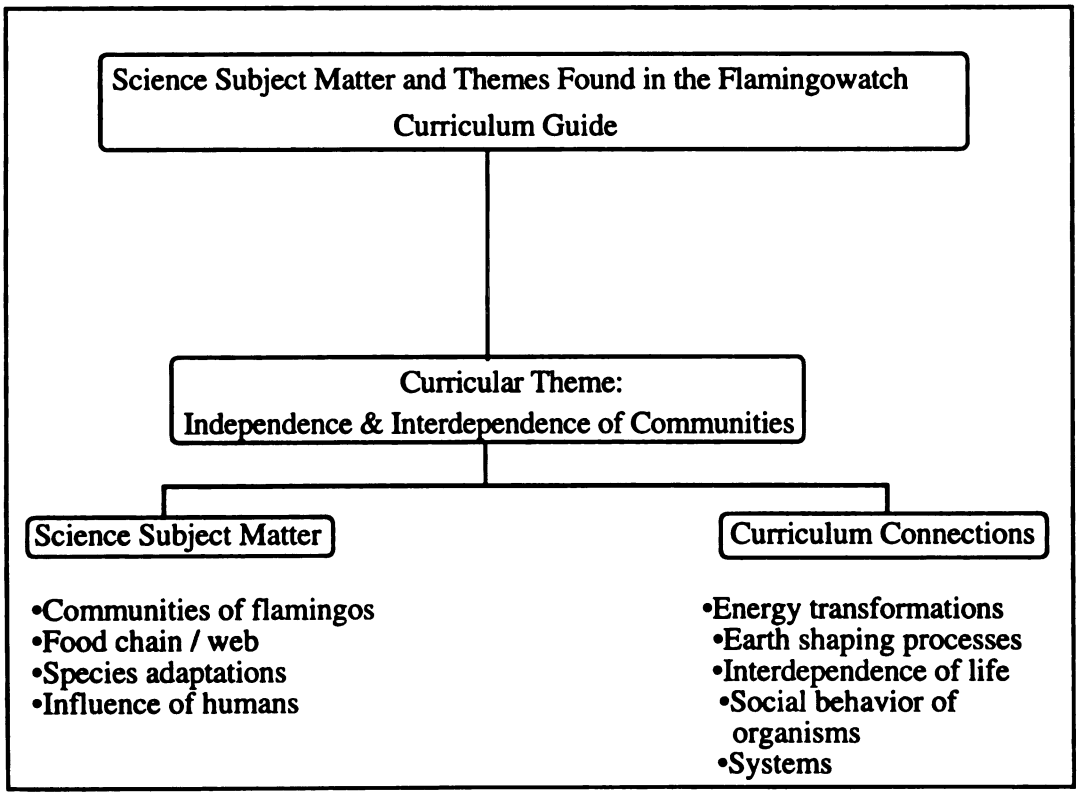


Figure 6 Fieldtrip Day 3: Independence and Interdependence of Communities

On day three, students focused on the independence and interdependence of species, specifically examining the communities of greater and lesser flamingos inhabiting the shores of the soda lakes.

> The food chain created around each lake is often fragile and tightly linked so that if one link is broken or weakened, the effects are quickly felt by the entire community.
>
> Flamingowatch Curriculum Guide

Students worldwide, through the live, interactive nature of the fieldtrip, joined Kenyan students as they toured Lake Nakuru National Park. Finally, students were taken behind the scenes to the "technology tent" which served as the nerve center of the fieldtrip broadcasts. The production studio coordinated live and taped images from fifty video cameras strung across a fifty mile stretch of the Rift Valley. The studio personnel also coordinated live and taped reports from experts in the field, and phoned-in, real-time questions from students worldwide.

To prepare her students for the science content and S-T-S issues embedded in the Flamingowatch curriculum (Yager, 1993), Ms. Brook utilized the CNN Video Reports prior to the fieldtrip. Following is a short description of the CNN Video Reports used by Ms. Brook.

Resource 1: CNN Video Reports for Flamingowatch

CNN Video Reports was a series of special video segments produced by the CNN Newsroom, a subsidiary of Turner Broadcasting. The segments were produced to support the major themes of the Flamingowatch electronic fieldtrip. The series of fourteen short video clips were aired by CNN Newsroom on January 30 and 31, 1995. Ms. Brook taped the segments to be used in conjunction with her implementation of the Flamingowatch project.

The video segments themselves consisted of current event reports that were germaine to the Flamingowatch project. The reports contained much color video photography and were densely packed with factual scientific and cultural information.

Each broadcast averaged about 2:20 minutes in length. Video topics included segments on: exotic species, plate tectonics, mythology, Nairobi National Park, and migration routes. Ms. Brook's use of the video clips is described later in this section.

Tools and Resources in the Curriculum Guide

The Flamingowatch curriculum guide contained extensive activities and strategies for teachers implementing the Flamingowatch project. The TOOLS and RESOURCES tables were constructed to cross-reference the dimensions of scientific literacy used in the coding schema (Ch. 3) with the activities in the curriculum guide. In analyzing those sections of the curriculum guide, I felt it necessary to amend the coding chart as follows:

1. category 7a was added to record activities in which students were asked to <u>collect</u> and <u>organize</u> data;
2. category 8a was added to record activities in which students were asked to <u>compare</u> and <u>contrast</u>, and/or <u>classify</u> information.

In looking at the Tools and Resources tables, the <u>MEGOSE</u> Dimensions of Scientific Literacy occupy the left column, and page numbers in the curriculum guide corresponding to the dimensions occupy the right column. Clearly, if students and teachers were to utilize the Tools and Resources sections in the curriculum guide, many dimensions of scientific literacy would be attended to. While containing a significant amount of science subject matter (Dimension 27 in each table), the problem-centered approach described in the Flamingowatch curriculum guide and the inquiry strategies described in the curriculum guide are also prevalent (see Dimensions 6-8a in each table). The following analysis looks at how specific dimensions of scientific literacy relate to the Flamingowatch curriculum guide. (MDE, 1991)

Table 13 Dimensions of Scientific Literacy: Flamingowatch Curriculum Guide Analysis TOOLS

Dimensions of Scientific Literacy	Tools Page Number
USING SCIENTIFIC KNOWLEDGE	
1. describing	11, 45,47,48,66,67,70
2. explaining	11,45,46,47,66,67,69,70
3. predicting	45,46,47,56,64,69,70
4. designing	11,46,47,50,51,67,68,70,71
CONSTRUCTING SCIENTIFIC KNOW.	
5. asking questions	11,46,50
6. solving problems	**Entire curriculum=problem-centered**
7. interpreting text and data	11,54,56,57,64,66
7a collecting and organizing data	50,51,52,53,54,55,56,57,58,59,60,61,63, 64,65,71,73
8. reconstructing knowledge	11,45,46,47,48,49,50,62,66,67,68,69
8a compare & contrast, classify	46,65
REFLECTING ON SCIENTIFIC KNOW.	
9. justifying	66,67,68,69,73,74
10. criticizing	66,69,73,74
11. describing limits	69
12. making connections	45,47,56,62,63,69,76
13. taking perspectives	46,50,51,69,76
14. S-T-S issues	69,70,76
15. nature of science and technology	
16. key concepts & theories of science	45,46
17. historical roots of science & tech	
18. habits of mind	11,46,67,69,70,73,74,76
REAL WORLD CONTEXTS	
19. human societies	70,71
20. technological systems	50, 51, 63, 71, 100, 137
21. the earth and space	45,47,53
22. physical systems	
23. living systems	46,47,48,49,50,51,52,53,54,55,56,57
OTHER CODES USED	
24. conducting an experiment	61,67,70
25. integrating science w/ other curricula	46,47,56
26. hands-on, active engagement	48,50,51,52,53,54
27. science subject matter	3,4,5,11,45,46,47,48,50,51,52,54,55,56, 62,69,70
INSTRUCTIONAL TECHNOLOGY	
T1 Using Internet	51,71,137,138,139,140
T2 Using tech to solve a problem	71
T3 Accessing information w/ technology	50.51.71.100.135.137.138.139.140
T4 Using interactive multimedia tech	50,51,63,71,100,135,137,138,139,140

Table 14 Dimensions of Scientific Literacy: Flamingowatch Curriculum Guide Analysis RESOURCES

Dimensions of Scientific Literacy	**Resources Page Number**
USING SCIENTIFIC KNOWLEDGE	
1. describing	102,105,107,108,111,113
2. explaining	103,104,105,107,108,109,111,113,117,119,120,122,123
3. predicting	105,107,108,120,122
4. designing	102,105,107,108,111,112,113,115,118,120,121,124
CONSTRUCTING SCIENTIFIC KNOW.	
5. asking questions	107,108,109,111,113,114
6. solving problems	**Entire curriculum=problem-centered**
7. interpreting text and data	102,103,104,108,109,119,121,122
7a collecting and organizing data	102,103,108,109,119,121,122,123,125
8. reconstructing knowledge	101,103,104,109,115,121,123
8a compare & contrast, classify	101,106,108,110,111,119
REFLECTING ON SCIENTIFIC KNOW.	
9. justifying	110
10. criticizing	110
11. describing limits	
12. making connections	103,104,108,109,110,113,114,124,126
13. taking perspectives	108,109,110,116,126
14. S-T-S issues	81,82,105,106,110,112,114,115,124
15. nature of science and technology	
16. key concepts & theories of science	100, 101-129
17. historical roots of science & tech	118
18. habits of mind	101,107,108,110,111,112,114,116,120,123,124,125,126
REAL WORLD CONTEXTS	
19. human societies	80,81,82,100,101,105,110
20. technological systems	
21. the earth and space	79,80,100,101,103,106
22. physical systems	
23. living systems	79,82,83,100,101,106,111,112,113-120
OTHER CODES USED	
24. conducting an experiment	102,103,104,108,109,122,123,124
25. integrating science w/ other curricula	101,105,114 **Entire Curriculum is Interdisciplinary**
26. hands-on, active engagement	101,102,103,104,105,106,107-115,119,120,121,122,123
27. science subject matter	79,80,81,82,83,84,85,86-99,100,101-129
INSTRUCTIONAL TECHNOLOGY	
T1 Using Internet	100,108
T2 Using tech to solve a problem	
T3 Accessing information w/ technology	79,80,81,82,83,114,115,119,121,126
T4 Using interactive multimedia tech	79,80,81,82,83,100,111,114,114,119,121,126

Flamingowatch Curriculum - Tools and Resources Analysis

Assertion 7
The technology-based Flamingowatch curriculum guide contains many activities, tools, and resources that correspond to the Dimensions of Scientific Literacy described in MEGOSE.

Scientifically literate students should be able to use, construct, and reflect on scientific knowledge (MDE, 1991). Evidence to support this assertion is found in Table 12 and Table 13 above and in analysis of specific activities found in these sections of the curriculum guide. According to the authors, the Flamingowatch curriculum is informed by current science education reform documents and thus, should be closely linked to the MEGOSE dimensions of scientific literacy (MDE, 1991).

> Social studies, science, language arts, problem solving, and study skills objectives are integrated into suggested activities. The underlying structure on which Flamingowatch is based is the *Benchmarks for Science Literacy of the American Association for the Advancement of Science*, published by Oxford University Press (1993). The content themes, overarching goals of the fieldtrip and all activities focus on competencies outlined in this excellent reference.
>
> Flamingowatch Curriculum Guide

Given that the authors of the Flamingowatch curriculum have based their work on the Benchmarks for Science Literacy (AAAS, 1993), and given that MEGOSE (MDE, 1991) was informed by Benchmarks, one would expect a high degree of scientific literacy to be represented in the curriculum guide. Table 13 indicates that the Using, Constructing, and Reflecting On dimensions of scientific literacy are well-represented in the Flamingowatch curriculum guide. Table 13 also indicates the distribution of dimensions of scientific literacy in the Tools section of the curriculum guide but does not indicate the frequency of the dimensions use in the guide. For example, Table 13 (Tools) indicates that **Explain** is found in activities on pages 11, 45, 46, 47, 66, 67, 69, and 70. **Describe, Predict,** and **Design** are also found on many pages of the curriculum guide. Table 15 below illustrates the number of times (frequency) each dimension of scientific literacy is used in the included activities.

Table 15 Frequency Distribution of Dimensions of Scientific Literacy - Sample Data

Dimension	Page Numbers	Number of Occurrences
Describe	11, 45, 47, 48, 66, 67, 70	7
Explain	11, 45, 46, 47, 66, 67, 69, 70	33
Predict	45, 46, 47, 56, 64, 67, 69, 70	9
Design	11, 46, 47, 48, 50, 51, 67, 68, 70, 71	15

While the describe and predict dimensions correlate about 1:1 with the number of occurrences per page, the explain and design dimensions occur with more frequency, sometimes occurring several times on one page.

The activities in the Flamingowatch curriculum guide frequently contain several of the dimensions of scientific literacy on one page or in one activity. These activities are organized on 'Student Worksheets' which the teacher may or may not distribute to students. Many of these worksheets also provide science subject matter in some way. For example, student worksheet T1a - The Big Picture: Constancy and Change provides students a summary paragraph on the science subject matter related to this particular theme. It also provides a list of resources to assist students in learning about the theme, and it provides a 'Questions for Discussion' section. Following are specific questions from this worksheet that correlate to the dimension of scientific literacy:

1. Describe the forces within the earth that have shaped the Great Rift Valley.

2. Read one or both of the famous stories by Dr. Seuss, *Horton Hears aWho,* or *The Lorax.* What do these modern fables have to say? How does it apply to the Great Rift Valley? Explain.

Worksheet T1b - The Big Picture: Observation and Inquiry is similar to worksheet T1a but asks students to compare and contrast, predict, and design in addition to describe and explain. Following are specific questions for discussion illustrating these dimensions of scientific literacy:

1. Compare and contrast the viewpoints of science and magic or ancient religious tradition. What does each viewpoint have to offer human beings? Is each a valid way to observe and seek understanding? Explain.

2. After reading about the flamingos, visualize or imagine the actual bird, not the plastic figures people use to decorate their lawns. What do you think a flock might look like from an airplane? From under the water? (both questions ask for predictions) Draw quick sketches, preferably appropriately colored, to show each idea. (design)

In addressing the questions in number one above, students would also implicitly be engaging in the habits of mind dimension of scientific literacy because they would be: evaluating claims and arguments, thinking critically, organizing and expressing ideas.

Resource 2 - The Nakuru Log

While reform rhetoric emphasizes teaching for conceptual understanding (MDE, 1991), content and factual information are necessary components of interdisciplinary curricula. As Buchmann (1984) argued, in order to teach, one must have considerable knowledge of content. Shulman (1986) and Wilson et al. (1987) also argued strongly that content knowledge was crucial to effective teaching. Likewise, students need access to information in order to pursue inquiry in the content area. The Nakuru Log is a series of short reports that provide factual information about the Lake Nakuru region of Kenya. Students accessed information from the log by reading the reports which were copied by Ms. Brook or by retrieving them electronically from America Online. The log in the Flamingowatch curriculum guide contains a summary of each report in the log as well as the full report itself. Each report is about 2-3 pages in length. These reports were used in conjunction with the CNN Video Reports to provide students with information about the

Great Rift Valley, Nairobi National Park, and the Lake Nakuru region of Kenya. The Nakuru Log Reports include:

- •A Shattered Piece of Wood: Geology of the Great Rift Valley;
- •Lake Nakuru National Park;
- •Rhino Rescue;
- •The Flamenco Flamingos;
- •The Man Who Shared His Hunt;
- •Why the Hyena Lives Alone.

The subject matter contained in the Nakuru log was useful in providing background information on the Great Rift Valley for Ms. Brook and her students. The short factual vignettes included information of a scientific, historical, mythical, and issues-related nature. For example, the *Rhino Rescue* section dealt with poaching and its effect on the diminishing rhino population in East Africa. Following is a summary of two sections of the Nakuru log that also were available in a much expanded version in the curriculum guide:

> A Shattered Piece of Wood: Geology of the Great Rift Valley. The geologic history of East Africa's Great Rift Valley is a tale of upheaval and change stretched out over millions of years. Slowly but surely the plates meeting at the Valley's center have separated. Volcanoes and earthquakes have marked the earth. Crystal clear alkaline lakes of waters have grown up. Life has spread its colorful covering over all.
>
> Flamingowatch Curriculum Guide

> Rhino Rescue. In 1969, in Kenya alone there were 20,000 black rhinos. By 1985 that number had dropped to 450. All over Africa and Asia the rhinoceros population has been decimated by poachers eager to cash in on markets in the Far East and in the Middle East. Kenya is one of several African nations aggressively protecting these animals. Lake Nakuru National Park is the first Kenyan sanctuary to play host to a small herd of both black and white African rhinos.
>
> Flamingowatch Curriculum Guide

Resource 3 - Activities in the Curriculum Guide

In an interdisciplinary curriculum, various disciplines are organized around a theme (Roberts and Kellough, 1996). The activities in this section of the curriculum guide reflect the three themes of the electronic fieldtrip: constancy and change, observation and inquiry, and independence and interdependence. Science subject matter is at the core of these activities and it is presented to students by asking them to be actively engaged with the subject matter. Students are asked to do research, write descriptions of geologic features of the Great Rift Valley, perform experiments, integrate science with literacy by reading parts of James Michener's epic *Hawaii,* and utilize multimedia videos that are related to the science subject matter presented in the electronic fieldtrip. Examples of activities found in the resources section of the curriculum guide include those listed below:

- View CNN mythology video clip then write your own myth about the Rift Valley;
- Create cartoon or storyboard illustrating the geologic rock cycle;
- Collect and examine soil samples from your back yard;
- Experiments and observations focusing on yeast, oxidation, carbonation;
- Researching to explain the saline content of the soda lakes in the Rift Valley;
- Conduct observations of insects and study their habitat;
- Study and share the myths and legends of East Africa;
- Play and analyze the "Camouflage Game."

Following is a more detailed descriptive summary of selected activities.

CNN Video Reports - Lasting two minutes and ten seconds, this video report describes the events surrounding the eruption of Mount St. Helens in 1980.

> The blast's magnitude took the northwest by surprise when Mount St. Helens erupted on May 18, 1980. Winds were clocked at speeds of 300 miles per hour, temperatures at 600 degrees F. The eruption flattened 3200 square miles of timberland. Hills and valleys were left lifeless. It looked like a moonscape and many believed it would be many years before life returned. But, that has not been the case.
>
> Flamingowatch Curriculum Guide

Why Is It Salty? - Students conduct two experiments to determine why the soda lakes in East Africa are high in salinity. In experiment one, students are asked to place a piece of chalk in a glass of water and allow it to soak for thirty minutes. They then record observations and results. In experiment two, students are asked to explore the concept of a closed system by evaporating a pie plate full of saline solution. To relate the experiments to their study of Lake Nakuru, the authors asked students to consider the following:

> Using concepts and data from the two experiments above, explain why Lake Nakuru is salty. What will happen to the salinity of the lake if the area receives more water than usual? What would happen in a drought? If either

of those two events occurred - too much water or too little - what might happen to the lake habitat? Connecting habitats? Explain.

Flamingowatch Curriculum Guide

These experiments are explained fully in Student Worksheet R4a. When keyed to the Dimensions of Scientific Literacy Chart, one finds this activity to be rich in activity pursuant to scientific literacy. For example, in doing the experiments, students are making observations, collecting and organizing data, and explaining their results. Students are asked to make several predictions, and make connections between what they learned in the experiment and how that information relates to a real environment in East Africa.

This section of the curriculum guide contains dozens more activities relating to the science subject matter about Africa's Great Rift Valley. As these examples suggest, students are asked to engage with the science subject matter in a variety of ways: conducting experiments; playing games and doing simulations; collecting, organizing, and interpreting data; analyzing and discussing video material; integrating literature with science in a variety of ways including reading and writing myths; and engaging in role playing activities based on issues such as the poaching of game and other issues such as habitat depletion. These types of learning activities are consistent with those that promote scientific literacy (MDE, 1991; NRC, 1996).

Flamingowatch was a project-based technology episode. Palincsar et al., (1993) described project-based learning as a pedagogy that engaged learners in the investigation of authentic problems, and an important part of the investigation involved communicating ideas to others. Developing problem solving skills is an integral component of scientific literacy and includes quantitative, communication, manual, and critical-response skills (AAAS, 1993). Meier et al., (1996) describe different problem solving models in their description of scientific inquiry. Palincsar et al., (1993) describe problem solving in relation to students' scientific literacy. In analyzing the Flamingowatch curriculum guide for this dimension of scientific literacy, I did not count pages nor evaluate frequency of occurrence. Rather, I listed in the Page Number column of Table 6: **Entire curriculum**

= **problem centered**. My reasoning here was that the curriculum guide was designed so that the majority of Tools and Resources in the guide would engage students in problem-solving of one type or another. To assist teachers in working through the science subject matter in the curriculum by using a problem-solving approach, the guide presents a specific problem-solving model called Presentation, Exploration, Synthesis, and Competence (PESC). While the curricular themes presented in the electronic fieldtrip curriculum are content-centered, the curriculum's heavy emphasis on research, problem-solving, and experimentation are based on the PESC model of inquiry. The authors of the Flamingowatch curriculum guide refer to this process as "the problem-centered approach" and describe it as such:

> The **Problem Centered Approach** uses problem solving to develop conceptual understanding. We call this approach the PESC Model. Following this path, students will identify a problem to solve or a question to answer. They will pull content from a variety of resources (including the fieldtrip) and employ a variety of skills to reach their goal.
>
> Flamingowatch Curriculum Guide

In suggesting this approach, the authors give wide latitude to teachers in both the amount of time devoted to this unit and the specific teaching strategies they might use. The decisions Ms. Brook made in implementing this model are examined later in this analysis.

Specifics of the PESC Model

The curriculum guide graphically lays out ten steps students proceed through in their application of the model. Students evaluate material presented in the fieldtrip and explore supplementary resources on the topics in the fieldtrip, narrow their interest, organize their data, and finally design a research project that helps them solve their problem or answer their question. Students utilize the tools and resources in the curriculum guide in moving through the problem-solving process. Competency is assessed through students presenting their results. Teachers are provided with very specific planning worksheets in the curriculum guide which address the following:

•time management plan;

•student ability levels;
•tools;
•resources.

The tools and resources included in the Flamingowatch curriculum guide are described in the guide as follows:

> Tools
>
> Tools T1-T5 are templates that can be applied to a number of learning situations as students work through the PESC model. They are always accompanied by student worksheets.
>
> Resources
>
> Resources R1-R4 are sources of information. They are intended to be explored by students and teachers in order to gather data as they work through the PESC model. Resources include:
>
> R1: CNN Video Reports - Information to view;
> R2 - The Nakuru Log - Information to read;
> R3 - The Fieldtrips - Information to view and with which to interact;
> R4 - Activities - Information to discover in direct experiences;
>
> Electronic Access - Information to read and write in interacting with on-line bulletin boards or a computer disk.
>
> Flamingowatch Curriculum Guide

Thus, while the fieldtrips provide students a conceptual, content-centered learning experience through the electronic fieldtrips, the overarching goal is to involve students in some type of research or investigation. The results of the investigations are then shared with the teacher and peers. Sharing the results of investigations, especially by using instructional technology, is consistent with the process of scientific inquiry described in both _Benchmarks_ (AAAS, 1993) and the _NSES_ (1996). In completing such an investigation, students would be engaged in many of the dimensions of scientific literacy represented in the _MEGOSE_ model including: _using_ scientific knowledge; _constructing_ scientific knowledge; _reflecting on_ scientific knowledge; and _integrating instructional technology_ into their investigations (MDE, 1991). In this section of the analysis, I will not provide examples of _every_ resource and activity that corresponds to the dimensions of scientific literacy, but will combine a few of the dimensions I feel are closely related and are demonstrated throughout the Flamingowatch curriculum guide.

Other MEGOSE Dimensions of Scientific Literacy

The analysis in this section is still providing evidence for Assertion 7. Later in the analysis, I shift from the document analysis to assertions about how Ms. Brook actually implemented the Flamingowatch curriculum.

Instructional technology should play an important role in curriculum integration (Roberts et al., 1996). Cox (1981) found that students' use of microcomputers facilitated improvement in their problem-solving skills and that the use of such technology was easily adapted to all subjects. The Flamingowatch curriculum guide and the electronic fieldtrips focused on subject matter that is thematic and integrated science, social science, literacy, art, and mathematics. Meier et al., (1996) described an interdisciplinary curriculum problem-solving model specific to science, mathematics, and technology curricula. In analyzing several problem-solving models, Meier et al., (1996) argued that for students to solve "real life" problems, they would need to be able to apply problem-solving skills in interdisciplinary situations. The problem-centered approach, the utilization of instructional technology, and the real-time interactive nature of the fieldtrips, situated students to utilize and explore science knowledge which was applied in a real-world context.

Dimensions of scientific literacy that are well-represented in the Flamingowatch curriculum guide and are closely related to the thematic, problem-centered approach of the curriculum guide include:

•#7a - collecting and organizing data;
•#23 - living systems;
•#26 - hands-on, active engagement;
•#27 - science subject matter.

In pursuing their research, students utilized instructional technology in a variety of ways, and specifically implemented the following instructional technology dimensions of scientific literacy:

•#T1 - using the Internet;
•#T2 - using technology to solve a problem;
•#T3 - accessing information with technology;
•#T4 - using interactive multimedia technology.

The Flamingowatch curriculum guide provides an extensive set of worksheets that enable students to gather, organize, and interpret data. Following is a list of the specific worksheets relevant to data collection:

•T3a - Gathering Data 1;
•T3b - Gathering Data 2;
•T4a - Habitat Survey: Environmental Conditions;
•T4b - Habitat Survey: Life Forms;
•T4c - Habitat Survey: A Transection;
•T5a - Animal Observation: Animal Data Sheet;
•T6a - Scientific Log: Observations;
•T10a - Identifying the Issues;
•T11b - Project Chart;
•T14a - Take a Stand.

These activities appear to be organized so that students are actively engaged in inquiries or investigations focusing on local flora and fauna, and habitats. Several worksheets focus on organizing data, identifying related issues, and pursuing a project. Thus, the curriculum guide focused students on science subject matter (primarily life science), engaged them actively with the subject matter, and promoted a problem centered-approach to learning. While the curriculum guide gives explicit instructions on how to utilize instructional strategies in the above activities, I prefer to analyze what this process actually looked like in its implementation in the next section.

Assertion 8
Ms. Brook modified the Flamingowatch curriculum guide and planned collaboratively for its implementation.

Flamingowatch - The Story in the Classroom

The purpose of this study was to develop a richer understanding of how Ms. Brook utilized instructional technology in teaching for scientific literacy. It "tells the story" of what such teaching and learning looks like in the classroom. The implementation of electronic fieldtrips and use of instructional technology to integrate current events into her curriculum were instrumental in this process. While the previous section carefully analyzed the Flamingowatch curriculum guide, this section examines what its implementation actually looked like in the classroom.

Even though the Flamingowatch fieldtrip lasted only three days, the supplementary activities provided in the curriculum guide and the electronic forums pre and post trip would have involved weeks or even months to complete in their entirety. What factors influenced Ms. Brook as she planned for and made decisions regarding how to implement Flamingowatch?

Instructional technologies have the potential to transform educational processes in ways that are largely unexplored in most elementary classrooms. Sanche et al., (1993) described the potential of utilizing instructional technology in co-planning and collaborating with colleagues. Traditional curriculum planning usually involves making short and long-term plans in advance of teaching a unit. However, technology-rich units of study such as Flamingowatch have some significant differences from traditionally planned units. One of the most significant differences is that because real-time use of instructional technology is utilized, planning and decision making are often done spontaneously, depending on what is being accomplished on-line. In implementing Flamingowatch, Ms. Brook typically planned a general framework of activities for the day, but remained flexible due to problems or surprises that could occur when using the Internet.

Collaborative unit planning among teachers is a desired practice in implementing thematic, interdisciplinary units as well as more traditional science units (Roberts et al., 1996; Dwyer et al., 1990; NRC, 1996). Brown and Logan (1993) described the value of collaboration among faculty by arguing that the greater the collaboration, the greater the facilitation of academic achievement. In planning for Flamingowatch, Ms. Brook and her colleagues established overall goals for the project prior to implementation. These goals included:

•participate in pre-trip activities;
•attend the fieldtrip;

•utilize the content and problem-centered approach spelled out in the curriculum guide;
•collaborate with other students and teachers through interactive multimedia technology.

These goals were planned collaboratively by Ms. Brook, Mr. Santo, and their colleagues at Lincoln School. The following diagram illustrates the collaborative relationships in the planning and implementation of Flamingowatch.

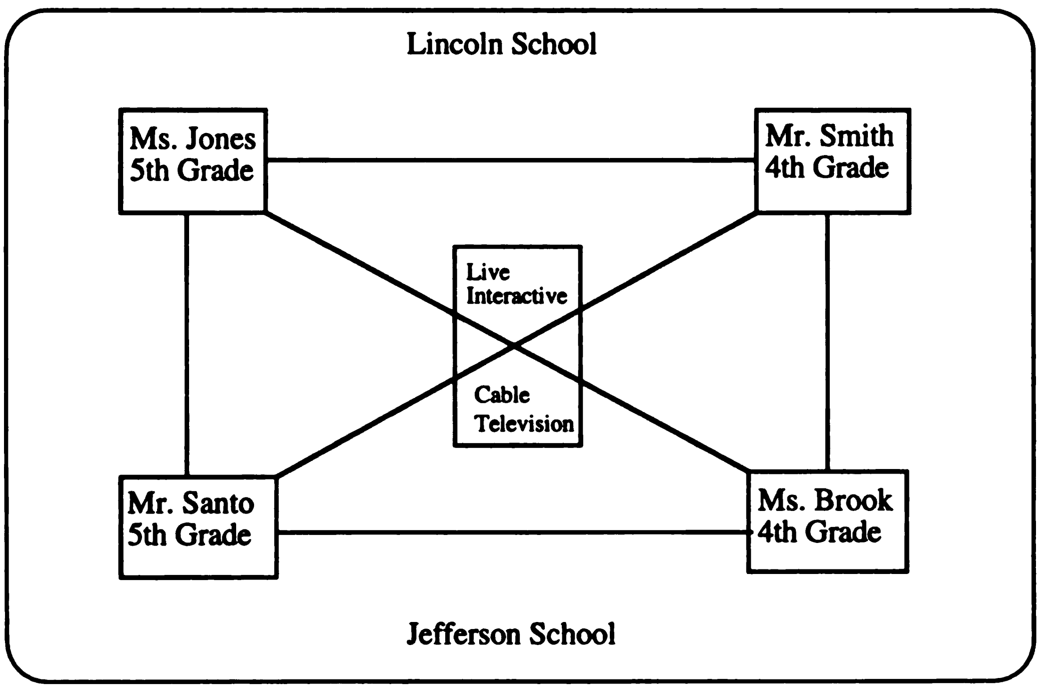


Figure 7 Planning: Prior To, During, and After the Flamingowatch Fieldtrip

In planning the overall goals for the project, all four teachers collaborated by using live, interactive cable television. In other words, even though they were in two different schools, they could see and hear each other in their respective classrooms. This greatly facilitated the planning process. This ability to work collaboratively with teachers in remote sites in real-time greatly contributed to the feasibility of implementing the electronic fieldtrip the way it was, and contributed to the idea that Ms. Brook worked in a technology-rich classroom. Ms. Brook commented on the technology-based planning process:

> Well, I guess realistically we couldn't have done these research teams from different schools without the technology because the likelihood of everybody sitting down face to face, it just wouldn't happen. Everybody's schedules are just too hectic. So, it made things smoother that way. And too, we're all pretty much of an attitude that this stuff works some of the time, and that's fine, and on the days that it doesn't, well, there you go..... (chuckling).......so it sure made it possible. It's a good connection because it's a real personal thing. We're past the barrier of "how do I look on TV" and we just act normal.

In this passage, Ms. Brook highlighted two themes relevant to this study: first, that instructional technology, though just a tool, facilitates a different type of learning, one emphasizing collaboration among teachers and students. Second, Ms. Brook felt strongly that curriculum must have a 'personal' connection to students' lives in order to be meaningful to them.

This teaching strategy emphasized a high degree of collaboration among teachers in planning for Flamingowatch, which differentiates it from traditional planning and teaching in isolation (Lortie, 1975). However, the great amount of content in the Flamingowatch curriculum guide and the ever-present dilemma of "time, or lack of it," also played a role in deciding how much of Flamingowatch to implement. When asked whether she used the Flamingowatch curriculum guide planning recommendations, Ms. Brook responded:

> I don't think I did. Our time was just too short, it was just plain old too short. We had at the same time report cards, conferences, every other subject to teach, you know........

Here, Ms. Brook illuminated briefly a dilemma faced by all teachers, that of deciding how to balance curricular projects with time frames that always seem too short. Walker (1990) argued that teachers most often considered content to be covered and what curriculum materials to use in planning their teaching activities. The major constraint in planning curriculum was teachers' lack of time due to their busy schedules (Walker, 1990). Also, in the case of the Flamingowatch curriculum, Ms. Brook dealt with another dilemma faced by teachers in general: how to translate high-level curricula into material that is age-appropriate for your class. Even though this was the third TAL curriculum Ms. Brook had implemented, she felt in general that Flamingowatch was way above the ability levels of her students. This was based on the suggested ability levels in the guide and her experience in implementing the Turner Active Learning Okefenokee Swamp fieldtrip earlier in the year. Given that the Flamingowatch activities were designed for lower, middle, and higher ability levels, I asked Ms. Brook to comment on how this affected her planning and whether the Flamingowatch curriculum was appropriate for fourth graders.

> Sure, yeah, our kids in 4th grade, definitely do only the lower activities. I found that it is hard for these kids to get........
>
> GC: Even the top kids?
>
> They're better at it.......but, you have to teach above the middle of the crowd but not into the top...........see.......
>
> GC: Did you feel that the Flamingowatch curriculum was geared to a higher grade level?
>
> Oh, absolutely! Yeah, I'd say that's middle to high school stuff. Almost everything in it. Last year we found that with the Gettysburg stuff we did. That fit our curriculum very neatly, but it is geared a bit higher.

In this respect, Ms. Brook's assessment of the appropriateness seems consistent with that of the authors of Flamingowatch. The activities in the curriculum guide keyed "advanced" are designed for middle school to high school ability levels. The activities keyed "basic" are for elementary to middle school ability levels. In choosing which "basic" activities to implement, Ms. Brook and her colleagues collectively decided which activities seemed most relevant to their goals and achievable by the fourth grade students.

As stated previously, planning for Flamingowatch and translating the curriculum guide required attending to issues of time, collaboration, and age appropriateness. Each teacher used the Flamingowatch curriculum guide and the planning sessions were mainly focused on the guide, or specifically how much of the guide to use. Ms. Brook commented on the Flamingowatch curriculum guide:

> The guide basically is above the ability level of most of my kids, but it is an excellent background for me because I didn't have any background in this kind of stuff. I read the whole curriculum guide, so for me, that was an important structure for how I could take it and translate it for 9 and 10 year-olds. (looking through the guide) Here's a section here on a project list. Because we worked with Lincoln, we decided our project collectively, rather than using, for example, this big video project they suggest in the

> curriculum guide. We looked at all of those lists of questions that go along with the project. Certainly though, all that stuff on the PESC model was stuff we used. I also used the beginning three pages where they overviewed the project very tightly to prepare the kids before the broadcast (fieldtrip). And then from there, we did some picking and choosing on what was realistic time-wise and interest-wise for my students. I also used the files from AOL a lot because that gave them (students) the background information. For instance, it would have paragraphs and paragraphs on different animals, different conservation groups that are working there in Kenya, um, maybe it was a couple of pages on a particular problem that's occurring there, so I used those a lot too......

I asked Ms. Brook to comment on how the Flamingowatch curriculum guide provided background on the content to be covered and how much of this type of material she used:

> Yeah, here's an example. (Looking through the Flamingowatch curriculum guide) Here's ten different ways in these worksheets of observing animals and sure, it is a real-world connection the way they're designed because they're to get kids doing observations and data collection in backyard projects, um huh. Even though I didn't use this guide page by page, I see here that they have a worksheet on 'taking a stand.' Certainly, many of the pieces that we used we did have kids take a stand then I'd pursue that with them on different issues they were studying and they had to augment any stand that they took with a lot of content. So, parts of the guide were the underlying current of a lot of lessons, but certainly not piece by piece from the guide.....

Thus, Ms. Brook described the practical way in which she and colleagues used portions of the guide but chose not to utilize the whole guide. Again, by reading the whole guide in preparation for designing lessons and implementing Flamingowatch, Ms. Brook demonstrated her propensity to learn. Following is a short description of what the live, interactive cable television planning sessions looked like.

Planning Sessions for Flamingowatch Using Live, Interactive Television

Planning sessions occurred during the teachers' lunch times, and typically lasted about thirty minutes. Because Mr. Santo's room had four television monitors and the live cable feed, his room was used for all broadcasts to Lincoln school. Because planning time was short, Ms. Brook felt it important to be prepared and utilized the time wisely:

> Just going into those planning sessions you really wanted to be prepared. From the lunch time hookup of the television and let's go on, you really wanted to be ready for it too.

The collaborative planning sessions occurred before and after the actual electronic field-trips. Table 16 below summarizes the content of the planning sessions.

Table 16 Content of Flamingowatch Planning Meetings

DATE	CONTENT OF MEETINGS
1/23/95	Curriculum Guide p. 69 - research questions Examined issues in guide Deciding on a 4th and 5th grade question Lining-up guest speakers on Kenya
1/27/95	Discussed talk show forums TBS to feature Jefferson & Lincoln in national piece Difficulty of getting Kenya experts Student research projects - topics Student research projects - students' choices
2/13/95	Planned the forum for students' presentations Concern over lack of research materials available to kids Use of Internet to assist students Getting "Hyena Lady" for the forum Plan forum at XYZ Cablevision
2/21/95	March 6 forum at XYZ Cablevision

The majority of the interactive planning sessions involved discussions about what research avenues the students would pursue, and making arrangements for the two culminating activities students would participate in. Ms. Brook communicated directly with her counterpart at Lincoln school, Mr. Smith, because they planned for each of their classes to present the results of their research findings to each other over the cable television hookup. Following are comments made during the planning sessions:

> Doug, do you want to figure out what we're gonna do with the fourth grade kids? Do you want to get together? Tomorrow? Let's just call each other, ok?
>
> SB: 2/13/95

> Doug and I are set - my kids are already working on their questions.
>
> SB: 2/21/95

A direct outcome of the February 13 planning session was a memo that Ms. Brook faxed to the two teachers at Lincoln school.

Following is a section of that faxed memo:

> POSSIBLE QUESTIONS FOR RESEARCH REPORTS: 4TH GRADE
>
> 1. Describe in detail the ecosystem in which your animal lives.
>
> 2. What is the main food source of your animal? Is there anything that is threatening that food source? What will your animal do if the food source is lessened or the food source disappears?
>
> 3. What are the characteristics of your animal that help it to survive in its habitat?
>
> 4. What is the climate in the ecosystem in which your animal lives? How is the animal suited to live in this climate?
>
> 5. Does your animal migrate? Why? Where?
>
> These are only preliminary notes on this, Doug. I'd like to sit down with you and develop some ideas in a more comprehensive manner so the kids have enough to go on independently. See you at noon on Monday.

Asked to relate the planning process to the Flamingowatch curriculum guide, Ms. Brook commented:

> We ended up trying to include all these major themes of um, the food chain and food web, and how the animal needs to fit in the ecosystem it lives in, and the whole idea of interdependence, of the people who live there as well as all the other animals, in those five questions. But rather than just say 'learn everything you can about your animal,' we sort of tied it in with those questions. It was a good lead into what the 5th graders do.....and that's what we were trying for.

Thus, after evaluating the content of the Flamingowatch curriculum guide and collaborating with Mr. Santo and their colleagues at Lincoln School, the research questions were generated. As Ms. Brook stated, the questions also were a "lead-in" to the 5th-grade science curriculum. After further meetings and discussions with Mr. Smith, the format of students' research reports was established. Following is a copy of the worksheet designed by Ms. Brook and Mr. Smith for their students.

FLAMINGOWATCH: ANIMAL RESEARCH

Your animal is: ____
Your name: ____

<u>In your research, you will need to answer the following questions</u>:

1. Describe in detail the ecosystem and climate in which your animal lives.

2. What is the main food source of your animal? Is there anything that is threatening that food source? What will your animal do if the food source is lessened or if the food source disappears?

3. What are the characteristics of your animal that help it to survive in its habitat?

4. Are humans sharing your animal's habitat? If so, in what ways? How are humans helping or harming your animal?

5. Does your animal migrate? Why? Where? Where else in the world is your animal found?

<u>Some hints as you begin your research</u>:

•Keep all of your notes and paperwork in the folder.
•List all of your sources while you work. You will need to write a bibliography for your report.
•You will need to use at least five different types of resources, so keep your eye out for different ways to learn about your animal. Some resources will probably be books, encyclopedias, videos, people, Internet, etc.
•Be prepared each day by bringing your materials to school. We will use school time for research, and having your materials with you each day will help you.

Figure 8 Worksheet for Flamingowatch

The due date and actual requirements for students' animal reports were distributed on a separate handout.

Finally, Ms. Brook discussed what the goals for the project were and some specifics about the collaborative planning process. I asked her to relate the planning process to the idea of concentrating on both content and problem-centered approaches:

> Yeah, I remember the PESC model and when Frank and Doug and Louise and I were trying to implement the model with the content in Flamingowatch, how could we get kids to do some problem solving and content, so both of those things were our goals for that......and granted all four of us working on this were at different points of motivation, desire, and information base and comfort with it, so it was interesting having the four of us talk and plan by cable connection..........but I remember going through the list of questions that were in the guide and then designing something entirely different with Doug, so that when the kids did those animal reports they had to do problem solving. We wanted to know how would kids use specific factual information. We had questions that tied into as many of the overall concepts that we could. But, having looked at the questions in the curriculum guide, we were able to devise our own......For instance, here in the experimental inquiry, talking about devising experiments about the salinity of the water and what makes the flamingo able to withstand that, we had a question about "Describe the ecosystem requirement or 'What characteristics did your animal have to survive its habitat?' So, all the facts about the animals contributed to answering these questions in their writing, taking the factual information and USING IT (her emphasis) for a much broader concept about adaptation, and survival and stuff like that. That's pretty complex for a fourth grader.

Thus, the planning and implementation of Flamingowatch, done collaboratively with three other teachers, was time-consuming and complex. The passage above provides a window into Ms. Brook's thinking about how teachers decide what is important in a particular unit of study and how they go about translating material for use with their own students. In describing that process, Ms. Brook also provides insight into how she sees the role of information and knowledge in the science classroom. She focused on science content, but also wanted the children to work through a problem solving process in discovering information about their particular animals. It is also clear that Ms. Brook feels strongly about the need to USE scientific knowledge, not merely accumulate a collection of factual information, a concept that is central to the dimensions of scientific literacy in MEGOSE (MDE, 1991).

Stages of the Fieldtrip

To "tell the story" of classroom interactions and what the actual implementation of Flamingowatch looked like, the following section will describe different stages of the project. The role of instructional technology and the role Ms. Brook played are embedded in the description of the project implementation.

Stage 1 - CNN Newsroom and the Fieldtrip

The Flamingowatch project was a very long, complex unit which occupied Ms. Brook and her students for about seven weeks. Throughout the implementation of this technology-rich curriculum, students were exposed to a variety of resources and activities that were both content and problem centered. In order to get students motivated for the fieldtrip and to provide them background information on material presented in the fieldtrip, Ms. Brook showed a series of short video clips produced by CNN Newsroom (the topics were outlined earlier). Because students had participated earlier in the year in another electronic fieldtrip to the Okefenokee Swamp in Georgia, they were familiar with the CNN video reports. Ms. Brook explained her motivation for using the CNN videos:

> We used those, um, CNN video reports a lot too and they really ended up with several different ways of viewing all this stuff that we were gonna do, um, for instance, they might do a clip......a two minute news clip on an animal but maybe another one they did was on how the animal was disappearing or about how this group of people were using the land and how that was infringing on the resources available......um, those really turned out to be a good way to give some authentic background information cause it was a news show that was happening NOW (her emphasis) about that particular area and in short enough chunks that they could still track with it. And I didn't get very specific on it just so that they could just get an overview on it...and we used the study guides I made up...I wanted to guide them through the specific stuff. Kids can be really flat viewers of, um, some stuff and television is a perfect example..they will sometimes just sit there and let it hit. So the worksheets helped focus their attention on something.

In describing pedagogical content knowledge, Shulman (1987) stated the importance of teachers understanding how topics, problems, or issues are organized and how they might best be represented to learners through the process of instruction. Cochran et al., (1993) offer an expanded view of pedagogical content knowledge which stresses, in part, teachers' knowledge of student characteristics and how students might respond in different learning contexts. In describing how she utilized the CNN video reports, Ms. Brook revealed clues as to her pedagogical content knowledge as well as her experience with how students sometimes respond to content delivered by television. Ms. Brook recognizes and appreciates the broad focus of the content and how it will relate closely to the information presented in the fieldtrip. The close correlation of the CNN video reports and the fieldtrip curriculum content is by design, not by accident, as both programs were produced by Turner Broadcasting. Ms. Brook recognizes the importance of the content being up-to-date by stating that the information is "authentic" and "happening now." Finally, Ms. Brook discussed her strategy to both 'focus' the students' viewing and record the subject matter by mentioning the worksheets she developed.

My observations indicated that as the CNN video reports were being broadcast, students were very busy trying to watch, listen, and fill in the worksheets. Below is an example of one worksheet Ms. Brook designed for the CNN Video Reports:
Clearly, the students completed the worksheets while watching the videos. However, the exercise appeared to be very demanding for students. In my notes I recorded:

> The video is very dense with arguments and factual information. Kids seem to be writing frantically to get it all down - even though the video only lasted about three minutes. As Ms. Brook is preparing for the video activity, she is cueing up the video because she had previewed the tape earlier that morning. As she is cueing the video, she says to students: I watched these this morning and they are sooooo real!

The activity in the worksheet for video #7 asks students to view the video **Forest of the Lost Child**, and record the viewpoints of the Masai people and the Kenyan government,

CNN VIDEO REPORT	CAUSE (the reason something happened)	EFFECT (what happened as a result of the cause)
ZEBRA MUSSEL INVASION		
EXOTIC WATERWEEDS		

Use these words to write a summary of the CNN Video Reports 3, 4, and 5 on volcanoes:

volcanic eruptions	moonscape
volcanic ash	climate changes
Mount St. Helens	force of nature

CNN Video Report 6: Hawaiians believe that Pele, the Goddess of Volcanoes, has a message for her people. What is the message?

Student answers to this worksheet are provided below.

Figure 9 CNN Video Reports: Flamingowatch

both of whom want control of this 300 square kilometer forest. In setting up the video with the students, Ms. Brook explains what she'd like them to do:

> I'd like you to think about the arguments that are being made - you've heard that there are always two sides to a story?
>
> Students respond......."yes"................
>
> In this video, they both bring good arguments. I don't know who's right - tell me what you think.

During the video, the classroom is absolutely silent, as students watch in rapt attention and write furiously on the worksheet. Ms. Brook is circulating through the classroom helping individual students. When the video finishes, Ms. Brook walks to the VCR and asks:

> Would anyone like to see the program again?
>
> Many students respond..........."yes"..............

Ms. Brook re-cues the video and shows it again, leaving one classroom light on so students can see the worksheets.

Although not every CNN video was shown twice, this account typifies the process of working through them. Much questioning took place after each video as Ms. Brook asked students for their opinions and honored their answers and opinions by frequently making statements such as:

> That's an important viewpoint - could you share that with everyone?

Throughout the 14-video series, I witnessed a variety of teaching strategies and activities that corresponded closely with the dimensions of scientific literacy advocated by MEGOSE. The worksheets themselves were designed after previewing each video and collectively they asked students to:

- think about cause and effect relationships;
- summarize the videos by writing summaries that incorporated vocabulary terms;
- take different perspectives;
- think critically, justifying and criticizing;
- convert information to a mathematical problem and seek the solution;
- write about S-T-S type issues;
- compare animal migrations in Kenya to those in their own state.

For each of the worksheets students were asked to do different types of writing. Each video was then followed by either a whole class or small group discussion.

After video #10, **Wildlife Deaths**, the discussion focused on fenced spaces, carrying capacity, etc. In discussing the concept of carrying capacity, Ms. Brook asked several students for their ideas. Several students gave verbal responses, after which Ms. Brook commented:

> OK, get into small groups. You can continue this discussion?
>
> Students.........."yes".....(emphatically)

The students immediately divided themselves into groups of four and separated out from other groups. Some groups sat on the floor, some remained at their desks, and some groups stood. As students discussed the traits of wild animals, Ms. Brook circulated around to each group, listening, and asking questions such as:

> Have you all heard of Critter Alley? You may want to write them questions along what we're discussing here today.

The reference to Critter Alley was an attempt to relate the video topics to students' real world, as this facility for wild and injured animals is located close to Jefferson and had been in the local news. This corresponding of science subject matter to students' real world was a strategy Ms. Brook employed often.

The CNN video reports were detailed and comprehensive, and provided students some of the content background they needed prior to taking the fieldtrip. The topics presented by the video reports corresponded closely with topics and issues embedded in the Flamingowatch curriculum. The descriptions above also indicate the close correspondence of Ms. Brook's teaching strategies to some of the dimensions of scientific literacy described in MEGOSE. For example, students asked questions, explained concepts, analyzed issues raised in the video reports, took perspectives, and wrote about scientific issues. Students' perspectives on the CNN Video Reports and other aspects of Flamingowatch are documented later in this analysis.

The Fieldtrips

This section describes all three electronic fieldtrips. The story of the fieldtrips is one of excitement, intense study and discussion, cutting edge technology, collaboration among teachers, and attention to the project by the local media.

In preparation for the fieldtrip, Ms. Brook had secured permission from parents and the principal to have her students come to school thirty minutes early each day for the three consecutive fieldtrip days. This was necessary because TAL scheduled the broadcasts for 8:30 am each day and school started at 9am. Because the broadcasts were live from East Africa, Ms. Brook and her students needed to be ready to go promptly at 8:30. On Day 1, Ms. Brook had arranged for a USGS geologist to address students' questions after the broadcast. Ms. Maki (pseudonym) from the USGS arrived with the idea that the content of the Day 1 fieldtrip would primarily deal with the geology of the Rift Valley. Ms. Brook was under that impression because she was planning according to the Flamingowatch curriculum guide. The subject matter of the video on Day 1, however, concentrated primarily on the colonies of Greater and Lesser flamingos, their characteristics, habitat, adaptations, etc.

At 8:29, the students are seated and waiting in anticipation of the fieldtrip. Ms. Brook had arranged the seats to simulate those on an airplane to enhance the feeling that "We were really going there." Just prior to the broadcast, Ms. Brook gave her final instructions:

> You'll need cards and something to write with. Mr. Coverdale and I will collect your questions and give you new cards - just raise your hand when you need a new one. I'll be on America Online (AOL) soon, and your questions will be put on the forum after the trip. Also, write some questions that you want to ask Ms. Maki after the trip.

At 8:31 am local time, the broadcast came on live from Kenya, filling the screen with millions of pink flamingos landing in Lake Nakuru. While the video was showing on the screen, there was no sound. Ms. Brook rushed from her AOL computer station in the back of the room to the VCR where she "fiddled with the VCR until 8:32 when the sound came on." Ms. Brook sighed, students clapped. Such was to be the routine during the three day fieldtrip. While the interactive videos were captivating, there was a fair amount of technological troubleshooting that was necessary each day. Ms. Brook proved to have not only a high degree of sophistication in her knowledge of instructional technology but also the persistence of a relentless troubleshooter and problem-solver. The point is that even when the teacher has the technical "know-how" to implement such curricula, serious technical problems are likely to occur during implementation .

By 8:40, students were raising their hands to give Ms. Brook their question cards. As Ms. Brook was very busy trying to get online with AOL, I circulated through the room attending to students' needs. This was to be my role throughout the fieldtrip, to assist Ms. Brook and/or students when they needed help. It was a very busy three days.

The fieldtrip moderator, Peggy Knapp, told students:

> This broadcast is coming LIVE from East Africa, in the Great Rift Valley. We are going to be trying to solve the great mystery of the flamingos and will be filming them with infrared cameras after dark to study the animals' night movements.

As the fieldtrip progressed, I made these comments in my notes:

> By 8:45, I have collected 30-40 note cards full of questions that will be entered into AOL for Kenya experts and other students to respond to. Also, students from other Jefferson classrooms are bringing questions down to Ms. Brook's room for the AOL forum. While the broadcast is being shown in different locations throughout the school, only Ms. Brook and Mr. Santo have Internet connections in their classrooms.

At 8:45, the moderator demonstrates the exciting, interactive nature of the fieldtrip by taking students' questions in real-time, from various geographic locations around the world.

> Peggy: Megan from the USA asks by satellite: "Why do flamingos stand on one foot?" (this question from Megan appears on the screen simultaneously with Peggy's reading it).
>
> Peggy: Just because it's comfortable.
>
> Peggy: From Millville, PA: "What would happen if the rift continued to move apart?"

> Peggy: As we speak, it is moving slowly apart, expanding the Valley's size....For more on that, let's go to our local experts.......

Thus, the fieldtrip continued with presenting the content while the moderator periodically took questions from students on AOL. During this process, Ms. Brook was busy booting her Macintosh and trying to find the AOL forum on Flamingowatch. My field notes indicate the next technological problem encountered:

> The AOL activity didn't go well. Ms. Brook couldn't get through into the right forum. Even though we dialed the AOL Help Line dozens of times, we couldn't get through for on-line help.

At 9:15 the video finished and Ms. Brook asked students to stretch, turn in their questions and sit around Ms. Maki. After introducing Ms. Maki to the students, Ms. Brook asked her:

> Why is this area of the world so different from the Midwest?

As Ms. Maki explained the geology of the Rift Valley, the students were very attentive and began to ask questions such as:

> Student 1: Why are there so many geysers in the Rift Valley?
>
> Student 2: Are the land forms because of the volcanic activity and isn't the ash rich so plants can grow there?
>
> Student 3: When one plate goes under, which one goes under?

This question and answer period continued until 9:56 am. The students had been actively involved with Ms. Maki for about forty minutes. As the questioning and discussion progressed, I became interested in the role Ms. Brook was playing. Just prior to the Flamingowatch fieldtrip, Kobe, Japan suffered a massive earthquake, killing between four and five thousand people. (The analysis of Ms. Brook's class involvement with that topic follows later in this chapter.) Several students began asking how the volcanic activity in Kenya might relate to or be similar to that which had occurred in Kobe. Thus, there was a connection between the students' learning while on the fieldtrip to that of their real world. As students continued to talk, Ms. Brook encouraged them to tell stories or ask questions about how volcanic activity or earth movements might have affected their lives. Students offered several comments and questions that had personal, real-world connections for them:

> Student 1: I got a magazine called *Discover* ....I've seen a lot about plate tectonics in it.......
>
> Student 2: How was the thumb of Michigan created?
>
> Student 3: (Responding to student 2) I heard the glaciers slowly pushed away the side of Michigan and then when they melted it formed the thumb and the Great Lakes.

As the discussion continued, Ms. Brook appeared to glow with satisfaction over her students' ability to be so actively engaged with the material. Periodically, as students were asking questions or explaining a point, Ms. Brook would look at me and wink or smile.

As the discussion wound down, Ms. Maki thanked the kids and announced her departure. Without prompting, the class began clapping and saying "Thanks for visiting us today."

After Ms. Maki departed, Ms. Brook began a debriefing session and gave instructions for the afternoon's activities:

> From 11-12 the next three days we're going to be on the talk show (AOL) forum. You'll have to miss recess time, but I'll make it up to you. For those of you with AOL at home, the talk show will also be on from 3-4 pm. If you have any trouble with your computer at home, call me at home and I'll help you out.

At 12:00 noon, the class began their work with the Flamingowatch AOL "talk show." Ms. Brook had finally reached the AOL Help Line and with their assistance, she successfully reached the forum. Each student was issued a blue worksheet titled: **Factoids: The Rift and the Lakes**. The sheet contained facts such as:

> 1. The Great Rift spans a massive 55 degrees of latitude and is 8,700 km long;
>
> 2. In places, volcanic debris in the Valley lies 3 km deep;
>
> 3. Every day, 15,000,000 gallons of poorly treated sewage enters Lake Nakuru.

After issuing the factoid sheets, Ms. Brook announced:

> You may want to use these fact sheets to help you get questions for AOL.

At this point, I was again interested in Ms. Brook's role - how she instructed students on using AOL to enter their questions into the forum. She invited about half the class to the computer while the other half remained in their seats working on unrelated mathematics activities. Ms. Brook modeled for students the process of progressing through the AOL menu to the Flamingowatch forum. When the forum was reached, Ms. Brook commented:

> OK, just give me a question and I'll type it in. While we're doing this, I need a reader to read the screen for us.

A student volunteered to read questions and answers off the computer screen. During this forum, students worldwide were entering their questions while experts at AOL were answering them. At the same time students were reading the screen, Ms. Brook was busy typing her students' questions into the forum. The questions originated from watching the fieldtrip broadcast and following is a sample of the students' questions:

> Student 1: We're wondering how you filmed the show when you were jumping from place to place.
>
> Student 2: When flamingos dive their heads into water, what kind of food are they diving for?
>
> Student 3: Is there any way to prevent the lake from drying out?
>
> Student 4: What's the main religion in Kenya?
>
> Student 5: How come when flamingos walk, they pick one foot up really far?

During this process, a question about algae arose. Ms. Brook stated:

> "want to know what you know about algae............

In less than a minute, a student entered the Flamingowatch online resource to investigate algae. A short discussion ensued, then they returned to the AOL talk show. As students continued to read questions and answers from the screen, Ms. Brook continued to enter questions into the talk show. I commented in my notes:

> This procedure is fairly confusing as some kids are reading off the monitor while others are verbally giving their questions to Ms. Brook. So many voices are heard at the same time. However, the kids seem very interested in the answers to their questions as evidenced by their further discussion of the answers they are receiving. They speak enthusiastically to each other and are generating a lot of noise - but it is constructive, busy noise.

When I interviewed Ms. Brook about the first day of the fieldtrip, she referred to some of the problematic aspects of it:

> This first day of the TAL looked like it was really gonna fit in with the earth's changes......but what they ended up doing on day one, during the fieldtrip, they didn't touch on this stuff at all! (she's pointing to Day 1 in the TAL curriculum guide) And I was really anxious. Here we had Ms. Maki sitting right there waiting to answer questions about the earth, and midway through she looked at me and said 'I don't know anything about flamingos!' I didn't know what was going to happen and that made it really uncomfortable because here I had a visitor in the classroom who came for one thing and.........
>
> GC: But, it went very well. The kids had a lot of good questions anyway.
>
> SB: Yeah, and they did recognize that a geologist wasn't going to be able to answer a whole lot of flamingo questions and they did direct their questions to the geology aspect, thank goodness! So, day one had a lot of stuff in the manual, this whole idea of the earth changes, we used a fair amount of that.

In a sense, Day 1 of the fieldtrip typified all three days. Each day involved watching the fieldtrip, writing questions, doing the AOL talk show, discussing issues, and relating the subject matter to Kobe and other topics of real-world interest and significance. Ms. Brook's role was very complex but essentially she facilitated the learning (Dwyer et al., 1991; NRC, 1996). In this instance, facilitating involved careful planning, mustering resources, developing curricula, keeping students involved with the interactive phases of the fieldtrips, and putting it all together during implementation. Over a period of three days, she coordinated the fieldtrip viewing, dealt with technological problems, modeled using AOL, assisted students with other types of Internet searches, brought in guest speakers, and still planned and taught the other subjects in her curriculum. In addition, she also seized the opportunity to use the technology provided her, and understood its capacity to contribute to students' learning. The classroom during the fieldtrips could best be described as a "beehive of activity." The excitement, especially on Day 1, was palpable.

Later in this section I will analyze and describe Day 2 and 3, but from the perspective of identifying other types of activities that occurred on those days. While equally active and exciting, the process was essentially the same as Day 1.

I have presented evidence to support the assertion that the Flamingowatch curriculum contained many of the dimensions of scientific literacy described in MEGOSE. In implementing the Flamingowatch project, Ms. Brook brought many resources to bear on issues and problems students were working on. Central to this study is how Ms. Brook utilized instructional technology in teaching for scientific literacy. To gain her perspective on the role of instructional technology in the Flamingowatch project, I asked her what role technology played in her being able to implement a curriculum like Flamingowatch:

> Well, it was a HUGE (her emphasis) part of it if you really think about it. You couldn't possibly get that feeling of how real it was without the videos, without all that live stuff happening, you know, and it was a combination of all of that. It wasn't just viewing a National Geographic video and learning about the animals, it was the short clips from CNN Newsroom combined with the files from AOL, combined with the text of the stuff that they were reading.........You know, that's an interesting part of it. That it was small chunks from a lot of different places that played into the whole picture, that's a pretty interesting thought when you stop and think about it, cause a lot of times, teachers will show an hour long video on something and then go into some lesson about it or some unit about it and yet we didn't use it in that way at all. It was a lot of short pieces used in many, many different ways. Um, the group for instance who ended up doing their animal report on the hyenas worked together at finding out what they could, they went into files on AOL to clarify some of their information, um, Vern wasn't even a part of that group but he was, he saw a television show happening and he called Louis who was part of that group and said tape this show.......so Louis did and he brought it in to his group and the three of them sat there and watched it and then while they were working on their report they would return to that film when they needed to so they used it much the same as you might pick up a book that you'd already read and flipped to a certain page cause you know that little piece of information was in there, they used the video in that way. That's pretty different for kids to use stuff like video or the AOL files and stuff like that. That's not typical of how most kids get information.........And this research stuff was real to these kids. It wasn't my project, it was theirs.

Solomon (1993) interviewed several technology-using teachers who described technology projects in which real-time learning was key in answering questions and solving problems. In a sense, Ms. Brook's perspective on the role of instructional technology in implementing Flamingowatch highlights her values and beliefs about using instructional technology and about what "the essence" of Flamingowatch was. Of major importance to Ms. Brook was using technology to present material that was live, in real-time. She also referred to the many different resources she used, or the fitting together of "chunks" that contributed to a holistic view of Flamingowatch. There also seemed to be a motivational aspect that was important - the idea that one student would call another to suggest taping material for their school research. Finally, the idea that students were using the technology to access information almost routinely and then sharing that information for a collective purpose seemed striking to Ms. Brook.

In returning to the MEGOSE dimensions of scientific literacy, I am drawn to the many dimensions that were apparent in children's learning during Flamingowatch. The focus on content, while also doing research and problem solving, all in a collaborative process, seems to be at the heart of the type of science learning advocated by MEGOSE. The critical thinking and habits of mind represented by MEGOSE occurred repeatedly in the implementation of Flamingowatch. Also, very important dimensions of scientific literacy such as integrated curriculum, using scientific knowledge to solve problems connected to students' real world were analyzed at the beginning of chapter four and appear again and again in this description of Flamingowatch. The students' use of instructional technology in studying science will be explored in more depth later in this chapter, but the Flamingowatch unit in itself demonstrates their interest and sophistication in using instructional technology to pursue scientific literacy.

Still, after months of classroom observations, I wondered whether the students understood the technology they were using. I asked Ms. Brook to comment on whether she thought the kids understood the technology they were using:

> No, do you think they need to understand it technically in order to use it? They don't need to..........(chuckling). I'm a user of the product and it's an essential tool, but I don't have to understand it technically in order to use it in my work.........Although, I think the kids do understand it fairly well technically. I think they understand it as much as most of us! I think they understood, for instance, that when they were talking on television with their partners, they understood that that signal was going from their classroom, to that green box, and from that green box it was traveling by wires to XYZ studio and then off to Lincoln......And I think they also understood that when Flamingowatch was coming through, it was going from Kenya to the satellite to XYZ and then to us, and I think they understood the distinction between how these things work. I think that's pretty sophisticated to know that kind of stuff........Now if you asked them today how did those signals go, they might not be able to tell you because

> it's not really important information. At that time, they were caught up in the events, the research, all the fun stuff of all the sights and sounds they were doing, and they also had some fun knowing that the technology was working that way. They got a big kick out of you saying "how did Helen do that?" (chuckling) That was pretty interesting I think to realize that we're all learning this together..............

Again, this insight highlights Ms. Brook's feeling that technology is just a tool, and that one doesn't necessarily have to understand it technically in order to utilize it. This passage also revealed that Ms. Brook also considered it interesting that "we're all learning this together....." In this respect, Ms. Brook does not see herself, or anyone, as the ultimate authority on technology use or learning in general, but instead sees learning about and with technology as a collective and ongoing process.

Even though Ms. Brook felt it unnecessary to understand the technology in order to use it, she seemed to have a good basic understanding of the technological processes involved in the Internet use and in the satellite technology utilized in Flamingowatch. As stated elsewhere in this study, Ms. Brook also demonstrated the characteristics of technological literacy described by Grejda and Smith (1994). And, in her opinion, the students also understood it, at least at the time they were using it.

To gain another perspective on whether students understood the technology they were using, I asked them several questions. First, I asked Jackie to explain the process of using technology to communicate with her colleagues at Lincoln school while doing the research project.

> Um, there was a video camera and it like focused on us and then through a line it went over to the Lincoln school and they saw what was happening in the camera on our TV and then when it was their turn to talk there a camera would be facing them and then we could see then talk......(she shows some satisfaction with her explanation)
>
> GC: Could you see them when you were talking into the camera?
>
> The other people could but we couldn't because we were facing into the camera and the TV was over there......one was over there and the other TV was over there and the camera was over there and so we couldn't see them when we were reporting (was pointing to where the camera and TV's were set up and showing some frustration with the technical setup)
>
> GC: It could be set up differently, better?

> Yeah, that would be better if we could see them when we were talking to them.......

In this passage, Jackie described the setup of the tripod and video camera during the research presentations as well as the technology involved in producing the live, interactive video reports. She realized the two schools were connected by "a line," and that when each group talked into the camera, their images were viewed in the other school. Jackie also seemed to understand a glitch in the setup of the technology as she described being frustrated at not being able to see her audience as she "reports" to the Lincoln children.

Given the frequency of Internet use in Ms. Brook's classroom, I wondered whether her students understood how that technology worked. Thus, I asked Jackie about the class's use of America Online.

> We talked to other people in other places and we asked them questions, we had talk shows........where everyone like where people can go in the talk show and they can talk about a topic like Flamingowatch and then they could ask other people questions while other people were asking questions.......

In Jackie's response above, she described what was done with AOL rather than how it actually worked. She described talking to other people in other places, and she described the "talk show" forum AOL sponsored during and after Flamingowatch. In order to push Jackie's thinking, I asked her where the "talk show" was.

> (Jackie is smiling) On the screen...on the computer screen and then uh, it would have who's talking and who's asking the questions and you just read what they say when they type it in.......we type in questions when we asked the experts things and then they can answer our questions......

Jackie responds by describing the talk show as being "on the screen." This answer does not reveal a deep understanding of the link-ups that create the Internet, but rather a more basic knowledge of using the computer monitor (screen) as the medium of exchange of ideas. Again, she described what students do on the talk shows: type in questions, ask questions, and consult experts.

In a separate interview, I asked Vern to describe why he thought Flamingowatch was considered an electronic fieldtrip and how computers were used during the fieldtrip.

> Cause, it's electronic, and it's through computers......and we're watching them, and hearing them, and talking to them, by electronics so I think that's why it is an electronic fieldtrip. We used the computers when we did Flamingowatch; we used them to type in our questions, to send them and when we were doing our reports we found information on the computers and I'd go home and my friend she has a computer, well, we both have a computer but hers has an encyclopedia and she got some information for me and it just gave some information and pictures, and electronic, I mean when we are communicating with our friends at Lincoln, um, that was electronics and that gave us a lot of information.........

In his response, Vern described not only using computers during Flamingowatch but precisely how they were used. He described "hearing them, watching them, and talking to them" by electronics. Like Jackie, Vern described the process of typing questions into the computer and sending them off. He also described using electronic encyclopedias at home to retrieve information related to the research project. When I pushed Vern's thinking about whom the questions were sent to, he replied:

> Well, we're sending them to the people in the Rift Valley to ask them questions about the ecosystem, and habitat, and animals, and the water, the lakes and there were lots of things we did not know and they gave a lot of information.......I think it was on Voyager.
>
> GC: So, the questions go from your classroom to Voyager to East Africa?
>
> Um, huh. Really quick! (chuckling)

In this passage, Vern described how the Internet was used to contact people in East Africa and retrieve information about the science content of Flamingowatch. Vern described the information about the ecosystem, habitat, animals, and lakes as being "things we did not know." He also seemed to understand that the class used Voyager as their Internet link and that their messages were transmitted "really quick." Thus, Vern went into more depth than Jackie regarding how the technology works. Still curious, I asked Vern to describe what the Internet is.

> Well, on the computer, there's all sorts of different companies like AOL, and some of them link together, like using AOL with Voyager, you can do that sometimes, but it's just like a big network of a whole bunch if different companies and uh, sometimes they might share ideas or, I don't know............

In this brief passage, Vern described different companies such as AOL and Voyager being linked, part of a network. He also described the purpose of this network as sharing ideas.

These responses indicate that students did in fact have a fairly sophisticated knowledge of the basics of the telecommunications they used on the various curricular projects. They definitely understood the speed at which the questions and electronic signals are sent "over the wire" and they had a good sense of how instructional technology was used in their study of science. That analysis is presented in chapter 7. In describing the live, interactive video transmissions from Jefferson to Lincoln school, Jackie indicated her knowledge of the process by critiquing how the equipment was arranged in the classroom, giving suggestions about how to improve the setup. All in all, I think the evidence supports Ms. Brook's assessment of students' knowledge of the technology.

Flamingowatch Days 2 and 3

Teachers' and students' use of instructional technology is frequently described in the literature as exciting and motivating (Dwyer et al., 1991; Bennett and King, 1991; Solomon, 1993; Bruder, 1993; Novelli, 1993). Day one of Flamingowatch had been exciting for students and for Ms. Brook. The video broadcast of the fieldtrip was visually stimulating and the live, interactive nature of the fieldtrip made students feel as if they were actually in East Africa. I introduce my analysis of the next portion of the fieldtrip through the vignette below:

> I arrived in Susan's classroom twenty minutes early, knowing the room would soon be busy with enthusiastic children anticipating their second fieldtrip. Susan gave me her usual enthusiastic greeting: "Hi, Greg!" We shared our usual banter as Susan moved around the room, checking and re-checking materials and equipment in preparation for the morning's fieldtrip. I prepared my field notebook and tape recorder, anticipating another morning of data collection. I asked if I could help and as usual, Susan put me to work. "Do you want to cut that paper into strips so the kids will have paper for their questions...?" For the next ten minutes, we both circulated around the room, from station to station, preparing the room for the fieldtrip. As I cut the strips of paper, our banter continued, both of us comfortable in sharing ideas and working together. "Susan, is everything with the VCR ok? Are we ready?" "Haaaaaaaa....I sure hope so. I hope they show the right program today. Gosh, they were supposed to do the geology part yesterday, but..." As she prepared the TV and video for

> reception, I booted the Macintosh computer, distributed the strips of paper to students' desks, and straightened the rows of desks so students would be in the same seating arrangement as the day before. "Gosh, Greg, this is exciting, isn't it?" Susan walked over and checked the Mac, negotiating through several menus on AOL until she found the one that would be launched first. "You know, Greg, I sure hope this AOL thing goes better today. I don't know if it's the Mac, or AOL, or what?" "It will, let's hope." "You know, Greg, we're going to have a lot of people here today...folks from the State Journal, a film crew from XYZ...I sure hope things go well...? "It'll go fine, I'm sure...I'll be taking lots of notes, but I'll be here to help too if you need it..." A smile passed across Susan's lips as she walked around the room, checking this and checking that. The TV was set to channel three. The volume was tested, then turned down. The blank tape was inserted into the VCR, then cued to position. As we continued to prepare for Day two, three students entered the room and went to their lockers. Susan watched them disrobe their winter clothes, glanced at me, and smiled broadly.

In this vignette, Ms. Brook prepares for Day two of the Flamingowatch broadcast. In part, Day 2 of Flamingowatch could be described as chaotic. While students were watching the live broadcast, and then later during the talk show session, a reporter from the local newspaper was in the room interviewing Ms. Brook and observing the process for an article he was writing on local schools' participation in Flamingowatch. While it was interesting having a reporter in the classroom, it was also somewhat distracting to students. Also present, and even more distracting was a film crew from XYZ Cablevision. They were filming students using the talk show forum and had a full battery of lights, cameras, and sound equipment in the classroom. Ms. Brook was interviewed on camera about her feelings about using multimedia technology in projects such as Flamingowatch.

During all the commotion, students were still fairly observant of the broadcast. When it ended at 9:15, students applauded, indicating their approval of the broadcast (an inference based on my months of observing the students' high level of engagement and positive attitudes). Ms. Brook invited the class over to the computer to do the talk show again, as I made notes about the "management" issues involved with using instructional technology in the classroom. Following is a comment from my notes based on my observations:

> One of the difficult management things about using AOL or any other on-line service in the classroom in real-time is the fact that you can't leave it

> booted very long due to the cost factor. Also for that reason, it is impractical to boot AOL in advance, before students arrive. They charge by the minute! Sometimes, spontaneous, real-time use of on-line services is a problem because as I've seen many times in this classroom, there are problems in connecting, the computer freezes, etc. When it freezes, you have to re-boot. Lots of things can go wrong.

Despite the many inherent problems with instructional technology (Dwyer et al., 1991; Itzkan, 1994), Ms. Brook used it consistently throughout the school year. Her feelings about teaching and learning with instructional technology were explored. A decision she seems to have made is that many of the types of curricular projects she's interested in would be virtually impossible to implement without the use of instructional technology. Thus, she has developed the propensity to work through problems in the interest of completing the projects.

Other than management issues, I was also interested in how Ms. Brook facilitated the discussion during the AOL talk show sessions. Two students were at the keyboard typing in questions, and Ms. Brook circulated around the other students, asking and answering questions. As I observed her in this role, I recorded the following observations:

> Ms. Brook deals with students' questions in interesting ways. She often replies to a question with 'I think we should read about that' or 'what do you think?' She rarely seems to offer a direct answer to students' questions. She spends a lot of time probing, asking students to clarify or say more about their answers, compares different students' comments, and makes connections between what different students are saying.

In this way, Ms. Brook effectively modeled the process of inquiry, and the importance of communication in studying science. It was also clear that by spending much time on students' questions, and seeking their input, she valued what they had to say. In doing so, Ms. Brook seemed to implement or demonstrate on a regular basis, many of the standards for science teaching described in the NSES (NRC, 1996).

Another questioning strategy that Ms. Brook used frequently was to direct a question back to the whole class for consideration. This is typified by Ms. Brook's comment below:

> Toby asks the question 'Is there any way to keep Lake Nakuru from drying up.' What do you think? (she directs the question to the whole class)

This invites a discussion that lasts for about ten minutes, in which most if not all of the students participate. Again, I comment in my notes:

> Again Ms. Brook redirects a student question to the whole class. Rather than her providing the answer to Toby's question, she asks the class to consider it. I have noticed on numerous occasions that the class in general is quick to respond to questions, whether posed by Ms. Brook or by another classmate. They are very engaged with the subject matter as they not only ask many questions on a regular basis, but also respond to questions asked by each other. They listen to each other! During this process, I have not witnessed any putdowns, laughing, or making fun of others. They are also very patient when a peer goes into a long, detailed explanation. They are willing to hear each other out.

In a sense, this analysis is peripheral to Flamingowatch, but it is also at the core of Flamingowatch. For students to work collectively to solve problems and effectively communicate, they must be engaged in curriculum projects that facilitate the collaboration (Palincsar et al., 1993). The NSES view of scientific inquiry and their description of teaching standards explicitly promote student collaboration and problem solving (NRC, 1996).

The Day 2 broadcast also produced a very exciting moment for students in Jefferson school. One of Mr. Santo's students, Sherry, was on the telephone, live to Kenya, during the broadcast. Some questions for Peggy Knapp came to her via AOL and some came live over the telephone. XYZ Cablevision had instructed Mr. Santo to have one of his students prepared with a question for Peggy and to place the call at a designated time. With a crew filming her, Sherry placed the call to Peggy Knapp and on cue from Peggy, Sherry identified herself as "Sherry from Jefferson School" and asked her question which was being broadcast live to a worldwide audience. When Sherry asked her question, Ms. Brook's students cheered loudly and clapped, enjoying the recognition of their efforts at Jefferson. The XYZ Cablevision clip of Sherry speaking to Peggy was incorporated into a documentary on students' participation in Flamingowatch.

Day 3 of Flamingowatch in most ways resembled days 1 and 2. There were more minutes devoted to taking live questions from students across the USA, which seemed to fascinate Ms. Brook's students. Ironically, technical problems plagued the Day 3 fieldtrip.

While the broadcast occurred without a hitch, connecting to AOL for the talk show continued to be problematic. Following is how I described it in my field notes:

> 9:01 We are still trying to get into AOL. There is a major bug as it simply will not boot properly. By this time, Ms. Brook is showing some frustration, but is not getting upset. She grabs her notebook with her notes on how to do different computer operations with different programs, etc. and looks up to see that we are booting it correctly. When she confirms this, she calls the assist number on the phone, which gives a recorded message. This day epitomized the technical problems that can occur when your lessons are planned around and depend heavily on technology. The connection never was made during this hour.
>
> 9:16 The video is over. We never could connect with AOL. Technical bugs in a project like this cause real problems. On-line support is not very good as voice mail and "waiting for the next representative" took the whole period. Still, it is interesting that Ms. Brook even had a phone in her classroom and could call out for on-line assistance - most classroom teachers do not have a telephone in their classrooms, so even if they do have the critical mass of technology to do a Flamingowatch-type project, they wouldn't probably have the phone itself to call for assistance. Mr. Santo comes into Ms. Brook's room to offer "I'm on-line if you want to come over and type in the kids' questions....." Ms. Brook and Mr. Santo confer, and Ms. Brook thanks Mr. Santo for the offer, but Ms. Brook did not go over and type in questions. The program was over and she had to attend to the class.
>
> 9:23 As kids are working quietly on their journals, Ms. Brook shares with me "last night I was on-line for over an hour trying to get some problems solved reusing AOL with the Turner Active Learning project. I didn't get the problems solved either...." Ms. Brook to students: "the stuff you're writing now we'll use in the future. The reason I had you write today is that your memory is still fresh." Although she openly shows frustration with the technical problems, she continues to work through them.
>
> COMMENT: The literature indicates that many teachers either give up on using technology or don't utilize it at all, in part, because of the technical difficulties. What makes Ms. Brook deal with the difficulties the way she does?

This passage reveals one aspect of using instructional technology that both focuses attention on Ms. Brook's high level of expertise and provides clues to why more teachers do not utilize instructional technology. Even though the video broadcast of Flamingowatch was successful, the AOL portion of the lesson was a technological nightmare. One cannot achieve anything on the Internet unless one can successfully connect to it. In this case, Ms. Brook tried valiantly, but was unable to connect to AOL or contact AOL for technical assistance. I have witnessed many teachers, after experiencing similar problems, proclaim their disgust with technology and refuse to use it again. Though not immune to frustration, Ms. Brook's typical response is to "get back up on the horse that threw her." I feel it is this response to adversity that helps make Ms. Brook an expert when it comes to utilizing instructional technology. In the next chapter, I talk more about the qualities that help define Ms. Brook as an exemplary technology-using teacher.

When the broadcast finished, Ms. Brook brought closure to this chapter of Flamingowatch by announcing to the class:

> We're going to continue our study of Kenya but the live portion is completed. I'd like you to write in your journal, to reflect on your experience over the three days of Flamingowatch. Think and write about:
>
> •what things amazed you;
> •what things you enjoyed seeing;
> •what things were exciting;
> •things you saw and would like to change or know more about.
>
> Please write uninterrupted for at least ten minutes. Also, my guess is that some of what you're writing is the facts you learned as well.

Several students assisted in going to the basket by Ms. Brook's desk and retrieving the materials they used to make their journals. They used a green cover page on the outside with lined paper inside. They stapled the papers together then folded them in half, so they had a top and bottom to write on. Most students made a drawing on the front of their journal - a sort of cover page. See the appendices for two students' journal responses.

In examining what the learning in a technology-rich classroom looks like, I have learned that the technology is only a part of the picture. Although the electronic fieldtrip and the AOL talk shows were central to Flamingowatch, other resources supplemented the project and I have already described some of them. The next part of this analysis focuses on the collaborative research students did and the culminating activity: sharing the research findings with their peers in Lincoln school.

Communication to Parents, Administrators, and Teachers

Although not central to this study, Ms. Brook's use of instructional technology to plan units and communicate is a part of the "story" of what her teaching in a technology-rich classroom looks like. Consistent with the science education program standards described in the NSES (NRC, 1996), Ms. Brook was diligent in her collaboration with other teachers, administrators, and parents. Each Friday, Ms. Brook used her computer to generate a letter to her students, which was delivered to parents. These letters outlined the week's curricular activities, special events, etc. This communication was one way in which Ms. Brook maintained a high parent involvement in classroom activities. Ms. Brook also filed a hard copy of each Friday letter, thereby keeping a fairly accurate record of what the class accomplished each week. Another perhaps implicit use of the Friday letter was to keep parents updated on the use of instructional technology in the classroom. The literature clearly indicates teachers' need of support from parents, administrators, and staff development professionals in order to obtain and maintain the critical mass of technology needed to integrate instructional technology across the curriculum as Ms. Brook does. The letter to parents dated 1-30-95 gave an overview of the Flamingowatch project that was taken from the curriculum guide and it also communicated the schedule of events during and after the actual fieldtrip. Her letter to parents effectively established the basis for my continuing analysis: description of the activities following Flamingowatch. Following is a section of Ms. Brook's 1-30-95 letter to parents:

> There are many parts to this fieldtrip that we have been or will be participating in:
>
> •Many students have done independent research on Kenya;
> •We viewed several segments of CNN Newsroom to learn about Kenya, endangered animals, etc.;
> •The live broadcasts on Feb. 1, 2, and 3;
> •Participation in America On-line talk shows that link our students to students throughout the world;
> •Ask the experts' forum on AOL.
>
> After the week of broadcasts:
>
> •Forming of small research teams with fourth and fifth graders at Jefferson and Lincoln schools; Communication will be via on-line cable television;
> •Designing a talk show to be broadcast on XYZ Cablevision. Program will be a panel of experts in the field of science and culture of Kenya.

The contents of the 1-30-95 communication to parents are good indicators of the dimensions of scientific literacy advocated by MEGOSE and other science education reform documents (MDE, 1991; NRC, 1996). The letter outlined a picture of students from two schools forming collaborative research groups, researching topics to do with aspects of the Great Rift Valley, and using live, real-time multimedia to communicate their findings. The following analysis focuses on how Ms. Brook and her students researched their topics and prepared for the "electronic forum" held with colleagues at Lincoln school. The analysis also examines issues such as students' use of instructional technology in the research process, how students learn to do research, and the role of the teacher as students actively engage in this process.

Students' Research and Information Technology

Jackson et al., (1994) examined the use of instructional technology in project-based elementary classrooms. Teachers in this study advocated the necessity of students working collaboratively on "truly current" (p. 20) problems. In order to facilitate project-based learning, effective planning is a necessity. Early in the planning process, the four teachers involved in Flamingowatch collectively decided that the fieldtrip would be followed by students' research projects on Kenya. Ms. Brook and Mr. Smith agreed that the fourth graders would form research teams to work on common topics, that is, a team at each school would research the same animal, then share their findings with the other team.

Ms. Brook's students were instructed to write a short essay explaining why they wished to research a particular animal. Each student selected and prioritized their top three choices and wrote their essay. An example of Susan's application essay is in the appendix.

Ms. Brook then read the essays and assigned students to groups, each focused on one particular animal to research. To prepare students to do research on their animals, Ms. Brook utilized three types of resources: the Internet, electronic library files that came with Flamingowatch, and a writing technique called "Quick-Way," a name Ms. Brook invented for the process.

Research began on 2-16-95. Rather than leading students to the library, Ms. Brook asked students to congregate around her personal powerbook computer which she brought in to class to allow students to research with. Using a strategy now familiar to students, Ms. Brook assigned seatwork to the class, then chose twelve students (half the class) to join her at the computer. The purpose was to model techniques in utilizing a part of the Internet called the World Wide Web (WWW). Ms. Brook's modeling of the use of instructional technology and how to implement it in scientific inquiry is consistent with the NSES science teaching standards (NRC, 1996). Ms. Brook always took responsibility for booting the computer, and her first task was to demonstrate how to move through the Web's menu to find different topics. The advantage of the WWW is that different libraries, museums, zoos, etc. throughout the world can be accessed. Combined with the CD-ROM encyclopedias students were already using, they were exposed to a vast amount of information that included text, graphics, photographs, data, and short video clips. Much of this information could be sorted, selected, and downloaded using the classroom's color printer. The school's library also had a computer with an internal CD-ROM drive, and the electronic encyclopedias for students to access. Thus, students had two different locations in the school to do their research, and many had similar facilities at home. In explaining the resources available to them, Ms. Brook began by stating:

> Children, one of your resources for this research will be computers. We have two here, and you might have one at home. You can get a printout of your animal and others' animals from the computer.
>
> Susan: I'm doing that at home on Encarta..........
>
> SB: We're going into the Internet, Susan. It is a s-w-e-e-t program. Susan, why don't you tell the class about it?
>
> Susan: There's more in the program than you can imagine!

While Susan described the WWW to the class, Ms. Brook booted a program called Netscape. She informed the class it is a program for navigating the Web, and pointed to several of the icons on the menu. This process of beginning the demonstration was interesting because it was not the teacher merely telling students what to do. Susan was asked to help explain her experience with the Internet, and all twelve students got to take a turn at the keyboard. This method of teaching students by modeling and actively engaging them in the process was the standard strategy for teaching new skills to the class. The pedagogical decision was to "train" half the class at a time to make the numbers more manageable. After everyone felt comfortable, the other half of the class would come to the computer and group one would return to their seatwork.

As the demonstration continued, Ms. Brook made a comment that indicated her enthusiasm for using instructional technology and gave students a realization of the power of the technology they were using:

> This screen on the computer is like having every library in the world open to you! It's not just libraries either. We can go to museums, zoos, anyplace!

The students seemed very excited as they shuffled to get a closer look at the computer screen and o-o-o-h-hed and a-a-a-h-h-hed quite a bit. Ms. Brook allowed and encouraged them to tell stories about their own computer use at home and the discourse continued for about five minutes after which Ms. Brook asked:

> Who wants to go to Busch Gardens?

She proceeded with the WWW demonstration, illustrating the different options on the menu, and explained how the WWW works. She finally selected a location called "The Electric Zoo," a place where students found information about their particular animals. Several different animals were located for demonstration purposes. Then, Ms. Brook gave some specific instructions:

> Now, when you use the computer, you'll be working two at a time. This will help you get the information very fast. If you have information on your computer at home, use that too. Please feel free to make printouts of your animals.

Following these instructions, Ms. Brook returned to the seatwork group and I remained with students at the computer, helping them where necessary, and learning along with them. Ms. Brook frequently utilized my presence in that way. To remind students of another source of information available to them, Ms. Brook announced:

> Would you please remember that you have teammates over at Lincoln school doing the same thing you are, so you can work with them too......

At this point I observed and commented in my notes:

> GC: There is no explanation at this point as to how students would work with the Lincoln students, but this statement serves to remind students that they are working collaboratively with the Lincoln students on the animal research project.

The final demonstration on the computer was a whole group activity and was conducted by a student. Hundreds of animal pictures came with the Flamingowatch curriculum and were available to download on the printer. This demonstration lasted only about five minutes, after which partners took turns booting and printing their animal graphics. Knowing that about six of her students had access to a computer at home, Ms. Brook finished the activity by announcing:

> What I'm showing you now is just some of the resources you can use in your report. Use your computer at home if you can and print pictures to share with others.

This introduction to the WWW lasted most of the morning, and gave students a powerful resource with which to begin their research. For the next several days, students worked on their animal research projects, utilizing a variety of resources in the classroom and the library. Many students were using their computers at home as well. Much of the content of Flamingowatch was presented and engaged with during the fieldtrip. Students were now engaged with the problem centered portion of Flamingowatch, preparing their research projects for the forum with students at Lincoln school. As students were working on their reports, I asked Ms. Brook to reflect on the science-related themes of Flamingowatch, how they related to her science curriculum and how she decided which themes to focus on.

> Well, I think we sort of hooked them with the discussion of animals. A lot of the animals in Flamingowatch are pretty unusual and fun to learn about so we sort of hooked right in there. It was really smooth then to go into the transition from the animals to the environment in which they live. So that while the idea of interdependence was able to serve a smooth transition, um, ...the flamingo for instance living in the soda lake. I mean the kids just thought soda lakes sounded like, you know, the Black Lagoon or I don't know what! So, it turned out that the environment itself for the Flamingowatch was as appealing as finding out about these different animals. The tie-ins with what they did with Okefenokee (a prior Turner

> Active Learning electronic fieldtrip) were really strong too because when they went to Okefenokee, they had already done a lot of wetland investigation here, then they went to Okefenokee where they had some of those same transition of the wetlands problems that we have here in Jefferson township to what was going on in Georgia, and they were able to take all that information and I think there was a fair amount of transfer of that information to Kenya also. So, there were a lot of things that were just smoothly interwoven, starting with the animals as a hook, and then going on to the topics of interdependency. They did a whole lot of stuff on Lake Nakuru, and which day did they interview those kids who live in Kenya? That had a big impact on the kids......that was really interesting because when they saw real children there and started sending questions to those kids, that was pretty cool, cause they then recognized that that is where these children lived, and so it was such a phenomenon to us, but that was their natural habitat.

The analysis in chapter 5 which explored Ms. Brook's knowledge, values, and beliefs about teaching and learning focused quite heavily on Ms. Brook's belief that learning must be in some way connected to students' real world. This belief is also one of the major aspects of the <u>MEGOSE</u> dimensions of scientific literacy, that students must <u>apply</u> knowledge in a <u>real-world</u> context (MDE, 1991). The passages above again highlight Ms. Brook's appreciation of learning that connects to students' real world, an aspect of science learning also emphasized by teachers in the study by Jackson et al., (1994). She also clearly explains the curricular connections between different projects the class had worked on. In preparation for the Okefenokee fieldtrip, which focused on the science and related issues surrounding wetlands, students studied the extensive wetland found in their local community. They then built on that knowledge by traveling to Georgia through the Okefenokee fieldtrip. Ms. Brook indicates that the curricular theme of interdependence in the Flamingowatch curriculum helped tie together these different learning experiences. Rather than viewing Flamingowatch as a technology-rich stand-alone project, Ms. Brook felt it fit tightly with the district's intended curriculum and with other projects in which students had been actively engaged with throughout the school year.

The Interactive Television Forum With Lincoln School

By March 29, students in both schools had completed their research and prepared for the sharing of information through the live, interactive multimedia forum connecting the two schools. The actual forum took parts of two different days to allow time for each group to present their findings. Technology played a primary role in the final implementation of Flamingowatch. However, as the previous analysis indicates, the technology itself sometimes presented a problem. Following are my notes describing the process of getting all the technology used in the forum up and running.

> This was one morning in which the use of technology raised its ugly head. The problems started when for some reason, Ms. Brook couldn't reach Lincoln on the phone. She needed to make some last minute plans, ask some questions, etc. At this point, my role transformed from an observer to an active participant as it did frequently if technical difficulties arose. While Ms. Brook and Mr. Santo continued working to get all the televisions working, I continued trying to reach Lincoln on the phone. Finally, Ms. Brook got through using another number, only to learn that Lincoln had faxed her with information the previous day but the fax was unsuccessful. Thus, the planning process was impeded. Ms. Brook and Mr. Santo had a lot of difficulty in setting the equipment up for transmission. They were unable to get the televisions in synch. Two televisions receive the video feed from Lincoln, and two monitor the feed from the video camera in Mr. Santo's room. Students in each classroom should be able to view themselves, and their peers in the other school. Mr. Santo is having a lot of trouble setting the sound level on the televisions which are producing a lot of feedback buzz. Finally, very near to broadcast time, we received the video but no audio from Lincoln. We could see them but not hear them. In this "high-tech" classroom, that problem was solved by holding up a sign in front of our video camera that said 'we can't hear you.' Finally, all the bugs were worked out and we were ready for the show to begin.

Ms. Brook and Mr. Santo had used the interactive video technology in Mr. Santo's classroom on many occasions. Nevertheless, as the passage above indicates, they had considerable difficulty in getting the equipment up-and-running to make the necessary connection with Lincoln school. Without a solution, the research presentation would have to be postponed. Rather than give up, Ms. Brook and Mr. Santo persisted until the technological bugs were worked out.

The Animal Research Presentations: Two Schools Cooperating Via Interactive Video

This portion of the analysis focuses on how the presentations took place, the role Ms. Brook played, and issues that arose during the presentations.

Ms. Brook began by giving instructions to students of both schools. Each group presented their findings, then students from the other school made comments or asked questions. Because the video cameras were on stationary tripods, each group moved to chairs placed in front of the cameras, then moved away after they were finished presenting. After the instructions, Ms. Brook announced:

Well, the kids on this end are interested in meeting their partners at Lincoln.

Several students squirmed in their seats and showed excitement on their faces. Finally, Ms. Brook asked her baboon group to move to the camera, and she gave more instructions:

> OK, let's start with some instructions. Each of you say your names, then the Lincoln kids will introduce themselves.

Ms. Brook then gave the order in which the other groups would present. As well as baboons, students had researched lions, warthogs, vultures, elephants, and zebras.

One by one, students introduced themselves and then the group reported on what they learned about baboons. Ms. Brook established her role early by asking clarifying questions such as:

> Now, Jackie, you're saying the baboons live in grassy areas, but your partner says they live in trees. Can anyone explain this?
>
> Jim: They graze in the open savanna but they sleep in trees for protection.
>
> SB: To the Lincoln kids, do you have anything to add or questions to ask?

At this point, Mr. Smith, one of the participating teachers at Lincoln joined the conversation by saying:

> This group used a lot of different books and they found conflicting information.........

Thus, the two teachers established their roles which primarily consisted of guiding the discussion by assisting students where they felt necessary, raising issues for discussion, and asking students for clarification. Ms. Brook responded to Mr. Smith's comment by stating:

> This might be an interesting question to ask the panel when we meet them on Monday, about the conflicting information we have found.

Ms. Brook is referring to a panel of experts on Kenya who were the subject of a program produced by XYZ Cablevision. Ms. Brook's students were the live audience for the panel and had an opportunity to address questions to the panel.

As the presentations continued, it became clear that for the most part, students were reporting factual information. Ms. Brook attempted to push their thinking by asking questions such as:

> Maria, could you give us a few more pieces about that? Why does migrating help the zebras? Could you tell us more about the teeth because yesterday you were describing something interesting about that?

This modeling of more probing questions seemed to influence the type of questions students asked, but only on a limited basis. For the most part, students reported their information from their research. During the presentations, I made notes about the role of the teachers:

> Both teachers not only push the students' thinking but also model the inquiry process by doing so. Their questions model the idea that good questions need to be asked and that sharing information is important and part of the collaboration process.

After recess, the students re-convened for more presentations. Ms. Brook said to them:

> Children, you are a wonderful audience for this project. You are listening and paying attention. If you are not the one speaking, you can 1) just listen; 2) write in your journal; or 3) read *Castle in the Attic.*

I had earlier noted that some students were not listening very carefully. However, it was apparently okay with Ms. Brook that students tuned out the process if they were not directly involved in presenting. I made this note in my journal:

> For some reason, Ms. Brook is giving them permission not to listen to other presentations. This seems to be at conflicting purposes. If sharing and collaboration are the goals, surely kids should be listening.

I am still unclear about Ms. Brook's motivations here and although I did not follow up on this issue, it was something I should have pursued further. I speculate that her instructions were given to occupy students who were getting restless due to the length of the

presentations. As the presentations continued, the issue that continued to emerge was that of conflicting information and what can be done when this occurs. At one juncture, a Lincoln student volunteered that his information on lions came from a book, and from *Encarta*, an electronic encyclopedia. Ms. Brook commented:

> If you can find a third source of information on a topic, it can verify your information.

One way that both teachers turned the issue of conflicting information into a positive issue was by suggesting that this is sometimes where research leads us. At one point, students were pondering how many hours a day lions spend sleeping and how many they spend prowling. The teachers piggybacked the conversation by saying:

> That's something we don't know, so we can go find out.

When the final presentation finished, the students all applauded themselves. They rearranged the classroom desks and assisted in cleaning up the room. Ms. Brook and Mr. Smith congratulated students and each other, then ended the broadcast.

Ms. Brook's Perceptions of the Presentations

Jackson et al., (1994) reported that elementary teachers in their study felt that the use of instructional technology in collaborative projects added a new dimension of "realness" (p. 21) to science study. Given that instructional technology played such a vital role in her students' collaborative research project, I was interested in how Ms. Brook perceived the experience of the live, interactive presentations and particularly the sharing and collaboration aspect of the project. I asked Ms. Brook how the research project's emphasis on sharing and cooperating fit with her ideas about science teaching and learning.

> The sharing itself, while it was happening, it was pretty obvious that this was or this could be used as a performance assessment. Those children knowing that they were going to be on screen needed to prepare ahead of time and then when they were on they wanted to be able to speak um, intelligently so that their partners over there could understand them and that in itself was a pretty decent assessment of where the children were at with their research. Also I think it brings it a little closer to that intrinsic motivation that we want kids to have..... it's also a way that the kids learned from each other with that because in the midst of it being motivation for further learning and assessment of the performance itself, the kids were

> in essence teaching each other, even if you weren't the team working on the rhinoceros, if you were sitting there listening to the team talking about the rhinoceros you were taking in that information in too.......

Ms. Brook viewed the whole process of preparing and implementing the live presentation with Lincoln school as an authentic assessment. It revealed "where they were with their research," and also facilitated an intelligent discussion among peers on a variety of research topics. Ms. Brook's argument that the research presentations represented authentic assessment is consistent with certain components of assessment described in the National Science Education Standards. For example, the Standards describe authentic assessment as "tasks that are similar in form to tasks in which students will engage in their lives outside the classroom" (NRC, 1996, p. 83). The Standards also argue that students should have adequate opportunity to demonstrate their achievements (NRC, 1996). This study indicates that all of Ms. Brook's students demonstrated their achievements through their active participation in the live, interactive research forum. Ms. Brook also suggested that the presentation promoted "intrinsic motivation," and through the presentations, students were in effect teaching themselves about rhinos and other topics.

Again, I focused Ms. Brook on the importance of sharing of information, asking her to describe the role information sharing plays in science learning.

> Part of the process is the processing of that information .....that's a pretty cool thing, because if um, if I don't have the sharing of the time, I'm missing an element that I have to have in order to take the learning further. Um, just for instance, remember that hard as ice stuff we were doing? A kid talked about a wet hand getting stuck on a screen door in the winter, and as we talked about it, she said "oh I didn't think it was glass I thought it was suction....." Now, I didn't think of it that way but it sure was important for me to have that information so if we had not done the sharing of information and the processing of what we were talking about, I would've missed that misconception.....

In this passage, Ms. Brook described the importance of processing and sharing information. She gave an example from a previous science unit, Hard as Ice, of a classroom discussion which revealed a student's misconception. She felt that through discussion and sharing ideas, she was able to "take the learning further." This passage also revealed Ms. Brook's awareness that students hold misconceptions about science concepts.

This study did not focus on how Ms. Brook dealt with students' misconceptions and this would be an area for further research.

Thus, the six week electronic fieldtrip and all related activities were finished. My analysis indicates that in many respects, the project actively engaged students in science content, collaborative research, writing and discussion of issues relevant to East Africa and society in general. Flamingowatch tied closely with the Okefenokee fieldtrip and wetland studies conducted earlier in the year. Many of the dimensions of scientific literacy were addressed (MDE, 1991; AAAS, 1993). Although I did not monitor the assessment of Flamingowatch for purposes of my analysis, Ms. Brook described the assessment as being the group report produced from the animal research as well as students' oral presentations using interactive television. This view of assessment is an important piece of Ms. Brook's view of scientific inquiry which I describe in detail in chapter 7. Students also participated in daily discussions about the content of Flamingowatch and completed several creative writing assignments and journal entries related to Flamingowatch activities.

In "telling the story" of the Flamingowatch project, I asked Ms. Brook to reflect on the positives and negatives of the project. She responded in great detail and in the process, discussed the role technology played in students' accessing information as they studied various aspects of the Great Rift Valley. The passage below is Ms. Brook's description of the pros and cons of the project:

> The positives.....those pictures on the video screen were so beautiful, weren't they? Wasn't it awesome!? When that guy was out there in the jeep and he was out there and you could see that lion and then they dubbed in a clip of a lion in the midst of a kill, you could not get that kind of a thing .....you just can't get that! (very enthusiastic in her description of the video and audio portions of Flamingowatch) You couldn't get it in a National Geographic television show and those things are awesome in them-selves.....And here it was really happening! What amazed the children too was when they met on screen those school children from Kenya, that was about as real life as we can get without going to Kenya! So, the fact that caused all of the information that these kids wanted to learn, it gave them that information in real-time, real life experience, that was really cool. The other thing was because that company produced such a good product, it gave me an awful lot of resources right at my fingertips. If a kid wanted to know the difference between the different types of giraffes, all we had to do was just go to that database that was on the computer and look it up and it

was sooo easy! Rather than just saying who wants to go to the library and look it up? The information was right there at our fingertips. The pictures and then the kids could print off the pictures so they could take a picture home with them, those kinds of things were a little bit of a glitz, but that kind of glitz really worked for them too. I guess they too had a sense that they were a real time part of it when they were sending their questions over and the questions were getting answered. When they said "Sherry from Jefferson, MI," that's real, they really did have a sense they were an integral part of the project.

GC: Were there any negatives?

Oh gosh, sure! Do you remember me taking that sledge hammer to the computer in the back of the room!? (laughing) The technology itself is definitely a headache. Um, part is the problem I had with the Macintosh........that was so hard and I never did straighten out that problem. I guess I'll just leave it till this summer to straighten out some problems and figure out how to make the Mac work better. There are problems in that regard. Um, John and I both feel that because we're all pretty new at this kind of stuff, and we're sort of on our own in the school in using this stuff as a way of learning, by being a pioneer out there, it means you have to go it the hard way. And you know if another teacher walked in next year and wanted to do.......we would've ironed out some of the headaches already and made it easier. But, we really ended up with headaches like that. Another thing is that because we are the first ones [in the school] trying it out there was a fair amount of public interest. We had XYZ Cablevision coming in with their cameras and Jefferson State Journal, our administrators, you want everything to go so smooth, but there's a fair amount of anxiety hoping everything was going to look really good.......And, future funding for this kind of stuff is always a question mark. Even though it is soooo beneficial to kids, you still have to sell it over and over and over to administrators because ....and so many people still perceive technology as being a frill in the budget and I think we used it as a really important tool for some really significant learning but people don't always see it that way and that's definitely a tough one because you really do have to sell it over and over again.

Although this passage is extensive, I included it verbatim as it captures Ms. Brook's enthusiasm for Flamingowatch as a curricular unit, and the powerful role instructional technology played in implementing the project. It also captures what she values and believes about science teaching.

According to Ms. Brook, the strong video and audio portions of Flamingowatch were unique in their portrayal of East Africa, and allowed students to access information in a live, interactive format. Ms. Brook enthusiastically stated "that was about as real-life as we can get without going to Kenya!" Ms. Brook also spoke highly of the quality of the materials provided in the Flamingowatch curriculum guide. She indicated the utility of the

Flamingowatch database, and the real-time "talk shows" or online chat sessions that allowed students to send questions off to experts and receive quick replies. This real-time interaction made students feel like they "were an integral part of the project."

Although Ms. Brook was very enthusiastic about Flamingowatch in general, she also described negative aspects of the project. Most of the negatives concerned glitches in the technology itself. While praising the role technology played, she also described it as "definitely a headache." Problems with the Mac, and other technical problems were evident throughout the project. But Ms. Brook also revealed that because of the newness of this kind of project, and due to the limited use of technology in the school, she and Mr. Santo were "being a pioneer out there," trying many things for the first time, and trying to work through the problems encountered.

Ms. Brook also described public interest in the project as being somewhat problematic. She described a high level of anxiety because she and Mr. Santo wanted "everything to go so smooth" and hoped "everything would look so good." During the project, her classroom was visited by myself, building administrators, XYZ Cablevision technicians, news reporters, television anchors, and many parents. Given the frailty of financial support for technology in the district, Ms. Brook was very concerned about how people would react to Flamingowatch and realized that part of her job was to sell the idea of utilizing technology to promote "significant learning."

Technology Episode 2: The Kobe Project

> One who lets slip the opportunity to serve another misses one of the richest experiences life has to offer.
>
> Pali Text

In describing a form of STS education called issue-oriented science, Thier and Nagle (1994) describe an approach to science teaching and learning in which students develop an understanding of the science and the problem-solving processes related to social issues. An example of issue-oriented science curriculum is the SEPUP program which derives its content from the world students live in. Thier and Nagle (1994) argue that this approach to science teaching will prepare students for citizenship in the 21st century. The Kobe project involved science teaching and learning, and like SEPUP, drew its content from the current events happening at the time. Throughout the Kobe project, I witnessed the deep commitment of Ms. Brook's students to helping others. Ms. Brook described Kobe as a "service project," and as the quote above attests, serving others is a rich experience. Ms. Brook and her students achieved a very rich experience while studying science, and utilizing technology to interact with people around the world who were also interested in the events unfolding in Kobe, Japan. I introduce the Kobe project through the following vignette:

> Having been told the Kobe project would be in full-swing, I arrived at Ms. Brook's classroom at 12:41 p.m., cappuccino in each hand, my notebook and tape recorder in my pack slung over my shoulder. I handed a cappuccino to Ms. Brook, who was surrounded by small groups of students busy working on various aspects of the Kobe project. As I took off my jacket, Jackie walked over to me and said "Are you going to work with us today?" "Sure, I'll just be a minute." As Jackie returned to her group, Ms. Brook gave me a brief description of what the different groups were working on. As I organized my research materials, Ms. Brook sat down at the Mac and began booting the Voyager program, grumbling about how slow the 2400 baud modem was. I glanced about the room and sensed the excitement, but there was something else in the room. I saw Jenny sitting alone at her desk, crying. Ms. Brook whispered to me: "Something to do with the twins day." We both nodded. As Ms. Brook took Jenny aside to talk with her, I went back to Jackie's table. She was working at a large round table with three other students. The table held an IBM 386 computer and a dot matrix printer. Jackie and Susan were composing a letter on paper to send to a contact they had made in Kobe. I was struck by the incredible amount of enthusiasm I saw in the room. Letters were being written, Kobe fund raising posters were being drawn and colored, and students were counting money they had already raised for the Kobe earthquake victims. Students circulated around the room, consulting each other, asking questions, approaching Ms. Brook, approaching me. Jackie and Susan took their rough draft of the letter over to the Mac which was booted into Voyager. "What are you doing now, I asked?" "We're going to send this off to Richard." "Who's Richard?" Jackie and Susan proceeded to describe who Richard was, how they got in touch with him, how he sent the class daily email messages describing the physical earthquake damage and the disaster relief effort for the victims. As they chatted with me, the two girls typed their letter on the screen, checking for accuracy. They were not too sure about the specifics of sending the letter, so they called Ms. Brook over to the computer. She talked them through the menu and the letter to Richard in Japan was sent. I circulated back to another table where four students were composing a letter to the State

> Journal for the fund raising effort. They outlined the letter on paper, then Vern moved to the IBM keyboard and began to compose the letter on the computer. As he typed, his colleagues discussed certain key words, modifying the text as they went along. When the letter was finished, they printed it off, satisfied looks all around. As the letter came off the printer, Vern crisply tore it away and brought it over to me. "Could you look at this for us?"

Flamingowatch was a technology-rich integrated curriculum project that was carefully planned for and implemented. While instructional technology was the critical element in its implementation, the project also involved students in much writing and discussion centered around a collaborative research component. Lasting for approximately six weeks, Flamingowatch was one of the major science projects of the year.

In contrast, "The Kobe Project" emerged into Ms. Brook's curriculum as a result of her using instructional technology in the classroom to monitor the world's current events. As the vignette above indicates, students were actively engaged in a science project that developed into a humanitarian relief effort. In mid-January, 1995, Kobe, Japan suffered a massive earthquake, killing thousands, and disrupting the lives of Kobe's population. Kobe's earthquake was the worst disaster to strike Japan since World War II. More than 5,500 people were killed while thousands more were injured. The earthquake measured "7" on Japan's Shindo intensity scale, making it the first earthquake ever to be rated at the top of the scale (Reid, 1995). Ms. Brook and her students were just beginning their Flamingowatch project, and were in the middle of reading *Sadako and the thousand paper cranes* by Eleanor Coerr. When a student asked innocently, "What can we do?," Ms. Brook and her students collectively decided to raise money in a humanitarian effort to support the people of Kobe. With that decision, the Kobe project was born.

In contrast to Flamingowatch, this project was almost entirely student-driven, with Ms. Brook facilitating their efforts. In her January 27th letter to parents, Ms. Brook reported:

> Dear Parents,
>
> Usually my Friday letter is addressed to the students, but today I would like to take the opportunity to thank all of you for sharing your child

with me. The children come to school ready to learn and bubbling with ideas. They make teaching fun and rewarding for me, and I hope I am providing an avenue of challenge and discovery for them.

In the midst of the academics - reading, math, social studies, science, writing - students are learning about the values of mutual respect, fairness, and cooperation. Some ways the values are taught in school are Mr. Erickson's morning announcements, Circle Time, class discussions, cooperative groups, and journals. Your child's participation in this week's "Kobe Project" is a fine example of taking the lessons learned at home and school to heart.

We watch "CNN Newsroom" several days a week, and keep abreast of current events around the world. Because the program is geared for middle school age and older, we watch only the portions that are pertinent to fourth grade students. Last week's earthquake in Japan caught our attention, and we interspersed viewing of the newscast with lessons about earthquakes. (The Earth's changes are one of the units of study in fourth grade science.) After viewing the program one day last week, there was a spontaneous reaction from the children wanting to help the people in Kobe. They quickly planned their action. They decided what needed to be done, and each day children signed up for committees, rotating jobs so that everyone had a chance to experience each part of the project. Here are some of the parts of their project:

•writing announcements to let our school know about Kobe, Japan, and to invite people to donate;
•making stickers with the Japanese word-picture for "friendship" on each;
•drawing posters to hang in the school;
•designing flyers to post at local businesses;
•counting donations and tallying the totals for each day;
•visiting each classroom for collections;
•searching the Internet for information about the latest earthquakes, and for information on Kobe, Japan;
•writing e-mail to the children in Kobe;
•faxing information to the local State Journal about their project;
•writing thank you letters to Mr. Coverdale (for presenting a slide show about Japan), Mr. Ziara (for providing the stickers), Mrs. Turney (for teaching us the Japanese word-picture for "friendship"), Mr. Erickson (for making each day's announcements);
•writing a newspaper article about the earthquake to send to the electronic school newspaper;
•celebrating each day's successes with classmates.

I am awed and overwhelmed by the outstanding response of the children as they work on this service project. They are demonstrating teamwork, creativity, and decision making, and utilizing the skills of writing, math, grammar, communication, problem solving as the work with each other. The children have commented on how important teamwork is to them, and this sense of community is apparent when I watch them working on the Kobe project.

Several parents have also been involved in this project. Some ways parents have helped are by getting information from computers about Japan, driving children to businesses to hang flyers, and donating to the earthquake fund. Most of all, BRAVO to the parents for the nurturing of your child's growth in becoming a caring and responsible citizen. Your child's work on this service project shows their action behind the lessons. Thank you again for your support to our endeavors at school.

Best Wishes,

Susan Brook

Bybee (1993) described the importance of including a focus on and understanding of community in a science education program. In doing so, he argued that "community" is a concept that should be expanded beyond the local to the global community. In studying the global community, Bybee (1993) argued the importance of promoting a high regard for the rest of humankind. Thus, science education should hold a place for studying issues that involve people in the global community. Ms. Brook's students' primary purpose in this project was to raise money for earthquake victims in Kobe. In doing so, they also demonstrated the power of instructional technology in the learning process and contextualized their learning in what was very much a "real world experience."

Students themselves decided what tasks needed to be done in order to raise the funds. They then divided themselves into work teams, dividing the labor and completing their tasks. Ms. Brook coordinated their efforts and facilitated by providing materials, working with administration and involving parents where possible. She also immediately utilized the Internet to establish contact with persons in Japan and around the United States who were also involved in relief efforts.

Students began each day by reviewing messages downloaded off the Internet regarding Kobe. Some messages led to class discussion, others led to action. Following are examples of messages taken from or sent out on the Internet's World Wide Web:

I just today found this address for information about the earthquake in Japan.
Japan earthquake: http//www.msen.com/emv/kobe.html

This site lists many kinds of information including lists of victims.

Sally Duncan
sallyd@tenet.edu

Students can get very current information about the Earthquake in Kobe by checking out the Home Page at: http//www.kobe-cufs.as.up/kobe-city/index.html

Messages can also be sent to KOBE@APIC.OR.JP

I hope one of these addresses will be of help for your students.
Susan Hixson

Some messages received on the Internet were graphic in their description, and sobering to Ms. Brook's students. Combined with the graphic images viewed on CNN Newsroom, the pictures and accounts of the tragedy in Kobe were shocking for many students. Following is one such message downloaded from WWW:

The earthquake damage to the city was so tremendous, it's hard to believe it's modern-day Kobe at all. The number of victims comes to over 4,000 missing or dead. Seeing a tragedy like this of such great proportion, it's hard to deal with the feelings of anger. Nobody knows what life will be like from now on, and Kobe is shrouded in anger and anxiety.

We are hoping the government and Self Defense Forces can react quickly, and that the people whose lives have been destroyed won't forget their civility and common sense. As for me, I'll be doing all I can, no matter how small of a role that may be, to help rebuild Kobe as quickly as possible.

Tohru Asai
Kobe Nishi High School
Kobe, Japan

The message above was received in Ms. Brook's classroom on 1-19-95 from a person named Richard who was monitoring and forwarding information from Japan. Written by a Japanese high school student, the message described Kobe's devastation, and the anxiety and uncertainty felt by the survivors. On January 27th, Ms. Brook's students drafted this memo and sent it out to Richard:

Dear Richard,

We read your message and we're sorry. We have been watching a news show called CNN Newsroom. It has been telling us information about Japan's quake. Our class has been collecting donations to help the people in Kobe, Japan. Every 50 cents they donate they get a Japanese word-picture

for 'friendship.' So far our money has risen to $313.36 and still coming.
We hope we can help Kobe, Japan.

Thank You,

From: Jackie, Susan, Jim, Beth, Vern

While students were drafting the letter to Richard, it was clear to me that students were very much aware of the implications of the disaster in Kobe. Having seen the images from CNN Newsroom, and read messages off the Internet, students began to translate the horror into what it might mean for them if such a disaster ever struck in Jefferson. Following is an excerpt from a conversation I had with Jackie and Susan as we waited for the letter to Richard to be drafted:

GC: That's a nice letter you're all sending out to Richard.

Susan: Yeah, maybe he can send it around to other people too.

GC: The money total is pretty impressive so far - you haven't been at it that long.

Susan: Yeah!! (very emphatic) I think we might get more too.

Jackie: Can you imagine what it would be like here? With the school crumbled down, no school.....and no water or electricity." (worried look on her face) "I just can't....those kids probably need pencils, paper, food, everything.....

Even though this conversation was fairly somber, I did not notice many others like it. Students were definitely upset emotionally, but they were not grim. Ms. Brook kept them very busy and focused on their relief effort, which helped take their minds away from the reality of the situation in Kobe. In doing so, Ms. Brook focused students' attention on the tasks at hand, and helped students participate fully in the scientific discourse during the Kobe project (NRC, 1996).

While I was struck by the intensity with which Ms. Brook's students were devoting themselves to the fund raising effort, I was trying to record their actions in my notes, and was particularly interested in their use of the technology available to them in their efforts.

My field notes from 1-25-95 paint a fairly clear picture of the activity in the classroom during these hectic Kobe sessions:

> Ms. Brook is busy logging onto Voyager to get on the Web. Mary, Sue, Vern, and Kelly are writing a letter to the electronic newsletter run by the Jefferson State Journal. As they type, they read the screen to the class and other students make suggestions about how to modify the message. Following is a representation of the letter which solicited donations from the wider community.
>
> E-E-E-A-A-A-R-R-T-T-T-Q-Q-Q-U-U-U-A-A-A-K-K-K-K-E-E-E!!!
>
> Disaster stuck Japan at 6am in Japan time. The destruction left over a quarter of a million people homeless and without food and water. Over 5,000 people have died or are missing and many are living in shelters. Houses have collapsed and many people have come back to find their buried valuables. You can help Kobe, Japan and the other wrecked cities by donating money to Ms. Brook of Jefferson Elementary school. We will forward the money to the Red Cross. Please send your money in an envelope with your return address. Every 50 cents you will receive a Japanese word-picture that means 'friendship.' Write checks out to Red Cross or call us at Jefferson school.

While this letter was being written on one computer, Jackie and Sally were using another computer to search the Internet for other Kobe addresses. At the same time, the two girls were explaining to others in the class about how to send messages to Kobe. I made the following comment in my notes:

> Everyone in the classroom is working on some aspect of the Kobe Project. Writing letters, making posters, coloring friendship stickers, and counting money already collected. Ms. Brook congratulated the class by stating "You guys are incredible - give yourselves a hand." Everyone claps with lots of smiles and looks of encouragement. There is a very positive atmosphere in the classroom. Students are actively involved in a meaningful project, a project that they themselves chose to do.

For over one week, students stayed very busy with the Kobe project, coming to school early and working through their lunch hours. Using technology to send and receive daily messages, and by viewing CNN Newsroom each morning, students were able to read the pulse of events as they unfolded in Kobe and across Japan. They were also spearheading the fundraising effort in Jefferson School, and in the greater metropolitan area. Using the Internet, Ms. Brook's class had appealed to other local schools, the news media, and the population in general for their donations to the Red Cross.

Students also received attention from two local newspapers with circulations in the thousands. Following is information that appeared with photographs in the local newspaper.

> The Jefferson News
> February, 1995
>
> For nearly a week the fourth graders in Ms. Brook's class at Jefferson elementary watched the plight of the earthquake victims in Kobe, Japan on the CNN Newsroom cable show. Then one of the kids said, "We can help these people," Brook said.
>
> In about nine days, the students raised close to $1200. Flyers, stickers, faxes, email, Internet - the students used every means possible to get their mission across to raise money for the victims and learn more about Japan.
>
> Through the Internet, students communicated with a Kobe resident who gave personal accounts of what was going on in the city.
>
> We received a real generous response from the community, Brook said. People who sent checks also wrote letters telling the kids they were doing a good job. For Brook, the whole experience was inspiring.

In evaluating and reflecting on her students' efforts in the Kobe project, Ms. Brook stated:

> The students not only knew they *could* help, they had a sense they *should* help.
>
> Ms. Brook, 1995

Bybee (1993) argued that global problems should be included in the science curriculum. Because of its nature, the Kobe project qualified as a current, global problem. Is this type of project really science learning? Some might argue that it was a tremendous personal learning experience for the children, but one that was not necessarily exclusive to science learning. On the other hand, my findings support an argument that this project was very much a science learning experience. Indeed, due largely to her utilization of instructional technology, Ms. Brook has developed new visions of what science curriculum is, and where to find it.

What made Kobe a science learning experience? First, there was a lot of information about earthquakes in general, and the earth building forces that contribute to tectonic activity, on the CNN Newsroom reports that students were watching daily on the television. The study of earthquakes was a part of the required fourth grade curriculum, so Ms. Brook was bound to teach about earthquakes at some point during the school year. As this study reports, Ms. Brook's students were studying the geology of Africa's Great Rift Valley concurrently with their participation in the Kobe project. Thus, students were able to make connections between the tectonic activity and seismic forces in two different regions of the world, a necessary component for developing scientific literacy (MDE, 1991). The gravity of the situation in Kobe gave students a sense of reality and urgency about their curriculum.

This section's description of the extensive writing Ms. Brook's students did during the Kobe project also indicates its value as a science activity. In their conception of scientific literacy, Glynn and Muth (1994) argue that writing can play a powerful role in learning science. Writing about science topics enables students to discover new ideas and clarify their thinking. Writing activities that engage science knowledge and process skills activate students' relevant world knowledge and provide real-world contexts that help ensure that science learning is not a rote experience but rather one that is constructive (Glynn and Muth, 1994).

There was also a literature connection to the Kobe project. Coincidentally, when the Kobe earthquake occurred, the class was reading *Sadako and the Thousand Paper Cranes*. While the theme of this novel is not seismic activity in the earth's crust, it did acquaint students with aspects of Japanese culture and history. To assist students in getting a feel for Japan, I showed them slides of my visits to Japan, which included views of Kobe, Osaka, and the Inland Sea area where the earthquake's epicenter was located. Thus, for several weeks, the curriculum was "packed" with a thematic, interdisciplinary look at science and cultural issues, including the geologic activity in Africa and Japan. If one examines the dimensions of scientific literacy in MEGOSE, several of the dimensions are featured prominently in the above activities. Specific objectives listed in MEGOSE that were covered during the Kobe project include:

C1: Generate reasonable questions about the world, based on observation.
C5: Develop strategies and skills for information gathering and problem solving.
C11: Use sources of information to help solve problems.
C21: Reconstruct previously learned knowledge.
R2: Describe the relationship of science to other forms of creative expression such as language arts and fine arts.
R3: Describe ways in which technology is used in everyday life.
R8: Show how common themes of science, mathematics, and technology apply in real-world contexts.
PME13: Describe energy and the many common forms it takes.
PMO2: Describe that forces are needed to speed up. slow down, stop, or change direction of an object.
EG1: Describe major features of the earth's surface.
EG2: Recognize and describe different types of earth materials.
EG4: Describe natural changes in the earth's surface.
EG7: Describe and identify surface features using maps.
EG8: Explain how rocks and minerals are formed (MDE, 1991).

Particularly pertinent in relation to students' work during this period are the following dimensions of scientific literacy:

•science subject matter;
•solving problems;
•habits of mind;
•comparing and contrasting;
•communicating about science and working collaboratively;
•Science-Technology-Society (S-T-S) issues.

Finally, in the MEGOSE conception of scientific literacy, implementation of science curriculum in a way that is meaningful in students' real world is a critical element. In this chapter, Ms. Brook spoke at length about the importance of connecting science curricula to students' real world experiences. In describing the relevance of utilizing instructional technology in projects such as Kobe, Itzkan (1994) stated:

> International collaborative programs have become "real world" oriented, with students doing hands-on projects that draw from or make contributions to their schools or communities. Ultimately we may come to see that students are global citizens in a world society, and that international networking initiatives are not just school projects, but vehicles for the exercise of citizenship (p. 64).

Kobe: The Insiders' Perspective

In closing my analysis of the Kobe project, I include a description of the project from the perspective of those on the inside: Ms. Brook and her students. I asked Ms.

Brook how the Kobe project came about and what role instructional technology played in it.

> It for sure was student initiated. The kids had been watching that CNN Newsroom everyday for the current events and each day they showed more and more about what was going on with the earthquake and Friday after the broadcast, they showed the number of the Red Cross on the screen and Becky Rant said, "Well, we can help them." And the whole class said, "Yeah, we can do that." And it was a very natural discussion that the kids had about it. Of course, I capitalized on it and said, "Well, what can you do?" It was really cool because they were figuring that they could do something to get money and later on in the morning Becky and Dorothy and Jackie offered to go ahead and call Red Cross, and even that in itself is technology that kids can use that they're not accustomed to, just walking over to a telephone in the classroom and doing it right then. And so they called and asked the Red Cross if they'd want food, or clothing, or money, or what and of course the Red Cross said money. And, then everything from then on, with a little guidance, came from them... they decided to write the morning announcements, talking about what and how they could go and collect money and stuff....the sticker idea was mine [the round sticker with 'friendship' in Japanese - one for each .50 contributed].
>
> And, then you [gc] helped a lot with just your slide show cause that was really timely because then they had pictures in their head of what Japan looks like and I found that was really important to them - they referred to that slide show several times - and at the same time they were reading Sadako and the Thousand Paper Cranes and ....

In this passage, Ms. Brook described the Kobe project as being student-initiated. Her students gathered information on Kobe as they monitored news from CNN Newsroom and decided collectively that "we can help them." Although Ms. Brook's students used a variety of media to help the Kobe residents, it was through utilizing telecommunications to interact with people in Kobe that made this project possible (Stahlhut, 1994; Rush, 1993). Ms. Brook facilitated the project by assisting with calling the Red Cross number from the classroom phone and the project was born. Ms. Brook's role as teacher during this project also reflected many of the standards for science teaching described in the <u>NSES</u> including: challenging students to accept and share responsibility for their own learning; structuring the time available so that students were able to engage in extended investigations; creating a setting for student work that was flexible and supportive of scientific inquiry; providing the science tools, including technological resources, necessary for scientific inquiry, and many others which I describe in chapter five (NRC, 1996).

I asked Ms. Brook to describe how she and the students used instructional technology as they proceeded with the project. The following passage describes her use of the Internet to get the most current information about day-to-day events in Kobe.

> I was just looking on email to find....actually I was using that listserv called KidSphere.......that had information on Kobe, different educators throughout the world subscribe to KidSphere and somebody put an address on it to contact people in Kobe, then I started looking in the Internet for some addresses and photographs and things like that [for Kobe] and showed that stuff to the kids. And then from that they [kids in class] were writing back to people in Kobe and they were saying "well, we're going to send this message to Richard...." Richard was just a contact person in Kobe but I mean, the kids were really connected! And I quit showing them pictures of the earthquake at that point because these people [the victims] were REAL (her emphasis) to them. Since then through KidSphere, they've heard about it from people from EVERYWHERE! (her emphasis) Just a couple of days ago, there was a letter on KidSphere from a 3rd grade teacher in northern Italy who had had a bake sale and raised $24 to send to Kobe so. The kids just read it, but we didn't respond.....it was just a little more connection for us [to Kobe].

In this passage, Ms. Brook described her use of the KidSphere listserv to gather up-to-date information and monitor what other students and teachers were doing to study the devastation in Kobe and support the people there. Ms. Brook stated that by using KidSphere, her students have "heard about it from people <u>everywhere</u>!"

Unlike Flamingowatch, there was no curriculum called "Kobe Earthquake." It was a current event that had generated the interest of students and teachers across the world. Thus, I asked Ms. Brook how this type of project fit into her science curricular goals and objectives. Ms. Brook responded:

> You have to do it then....I mean, it's happening right then......you can't just ignore it and go on......I mean I was doing a unit on force and motion when all that started and that's been on the shelf ever since......... Earthquakes, fortunately for me is part of the 4th grade curriculum, but I would do it anyway even if it wasn't.....I guess I'd find a connection. Current events is supposed to be part of everybody's curriculum and that's more of an unspoken expectation, but it is universal, you should be teaching current events......but to be effective as a teacher, you do it...... World geography is supposed to be part of 4th grade curriculum too so, why not?"

In this passage, Ms. Brook described the importance of integrating current events into her science and social studies curricula, and capitalizing on events as they happen. Teachers need flexibility and control to be able to experiment in classrooms (Bruder, 1993).

Because current events are, by definition, current, one must be willing to take a flexible approach in planning and teaching in order to integrate a study of the event into the curriculum (Bennett and King, 1991). Ms. Brook illustrated this flexibility by stating that she interrupted her unit on force and motion in order to concentrate on Kobe. Even though the concepts of force and motion are integral to the study of earthquakes, Ms. Brook taught force and motion primarily from a physical science perspective, using simple machines and toys to demonstrate the concepts. However, since world geography and the study of earthquakes were part of the curricular requirements for fourth grade, the Kobe project facilitated covering those objectives.

Throughout this study, Ms. Brook emphasized the importance she placed on real-world curricular connections to students' lives. In the passage below, Ms. Brook described how technology used in the Kobe project helped foster personal connections between her students and others throughout the world with similar interests in the Kobe earthquake and events that followed.

> I think the technology end of it made a personal connection on a world basis....I mean, like last week when they [the class] read that letter from the teacher in northern Italy, these kids didn't even blink an eye! The kids are just so global now with their connections. Using tech is not normal for them quite yet because they know that they're the only class that's doing it and they know that other classes don't have that opportunity, but they know that it is part of their learning I guess....yeah, they do! Isn't that neat?! Yes, you know Greg you could've done that whole project without technology and that would've been OK too, but it would've been less personal, less connected, we're here and they're there.....with the email, I think they were much more connected.......

This study focused on how an elementary teacher utilized instructional technology in teaching for scientific literacy. Given Ms. Brook's extensive use of current events and various global activities as curricular foci, it seemed evident that she must position herself to move quickly in terms of planning and implementing lessons which utilized technology for studying events such as Kobe. How did Ms. Brook prepare herself to be positioned for the quick thrust into a technology project? In the passage below, Ms. Brook described how she prepared for teaching units such as the Kobe project.

> I always find I need a lot of background when I teach science because I don't know a lot of stuff about science.........I use a lot of stuff when I'm trying to design a unit, a lot of books, magazines, Internet, electronic encyclopedia, all that kind of stuff.......there's a program on CD-ROM called Science Cap...... that has a lot of background information, experiments, etc. and I use that for background information.........I've been using it [Science Cap] a lot just for all that background stuff........ This technology is just great for doing research, it sorts topics out every which way and it allows you to look at all types of related information too.....do you see what I'm saying? The flood of information is a lot quicker than it ever has been before and in much greater depth, that is the CD-ROMS, etc. are in more depth than traditional stuff like encyclopedias, and I think we learn much quicker now than we ever did before........ And one thing you really want kids to do is helping your kids to be critical thinkers.........well, I think that when we're talking about what our kids do with technology, and in the way the computer allows kids to refine and refine their work, this is critical thinking in the best application cause the kids are using these tools to get to something else rather than using logic exercises out of any sort of context...........using technology is related to something meaningful in critical thinking.....

Thus, Ms. Brook stressed her need to bolster her own background knowledge of science and her use of technology in doing so. In this passage, she described utilizing CD-ROM software that provided effective research capability and programs such as Science Cap that provided science content and experiments.

Ms. Brook also suggested that the newest technology allowed students to hone their critical thinking skills by working on real-world problems (Viau, 1994; MDE, 1991). Below, she contrasted a few of the technology projects the class had completed and discussed their real-world applicability, admitting that solving real problems is difficult for teachers to think about and plan.

> Application of something that is real is one of the hardest things that a teacher tries to find. How do you create a learning situation that is real to the students? Now, that Kobe thing and the Haiti thing worked out to be that way. This Flamingowatch project is once-removed but it's pretty close....... it's once-removed because it is a teacher directed activity in that it was my decision, not theirs, to actually do the project, so to get something that applies to their real-world is hard.....and coming up with that real-world situation is the hard thing. There can be teacher generated like doing that stuff on force and motion I can tie it into activities that I provide for the kids or to some kind of anticipatory set in the beginning to get them wondering about what will happen, but that's still coming from me......... that's probably the best reason too to go with the technology related projects, like Kobe, because it was happening, it was real to all of us, I didn't have to generate interest in earthquakes - it was there! Hum?! So, think about it.

In this passage, Ms. Brook described the Kobe project as one that was student initiated, inspired by their monitoring of CNN Newsroom, and driven by the children's utilization of instructional technology.

My analysis of the Kobe project indicated that in terms of the MEGOSE dimensions of scientific literacy, many were represented in the students' work on the project. The science content also dovetailed nicely with the fourth grade intended science curriculum and with other technology-rich projects such as Flamingowatch. Additionally, the Kobe project provided students a very valuable experience that connected to their real lives. Interpretation in this section described the importance of what White (1994) refered to as the social relevance conception of education: preparing students to contribute to the larger social structure. In doing so, the role of the teacher is to identify social problems and facilitate inquiry into those problems by a democratic community of learners. Due to the humanitarian aspects of the Kobe project, Ms. Brook's students did inquiry into a social "problem," which could better be described as a human catastrophe. Also, Ms. Brook deviated from White's view of the role of the teacher in that the students actually identified the need to pursue the Kobe project, Ms. Brook then facilitated the process.

Technology Episode 3: The 1995 Iditarod Sled Dog Race

This section of the analysis is relatively brief, but is included for two reasons:

1. Ms. Brook regularly involved her class in smaller Internet projects;
2. Using instructional technology in this way contrasts vividly with projects such as Flamingowatch, Kobe, and the daily use of instructional technology as a tool to complete assignments, plan units, etc.

"Cruising the Internet" is a phrase that means taking a look at what is out there in terms of what other classes and teachers are doing, as well as examining the content of portions of the Internet to see if they can connect to or supplement the regular curriculum. It is also a way to get the most up-to-date information on current events as they happen across the world. When Ms. Brook cruised the Internet, and she did so regularly, she frequently found "snapshots" of information that did indeed supplement her curriculum or were interesting and relevant enough to be brought into class discussions.

One of the largest forums on the Internet for finding such current and interesting information is a forum for elementary educators called KidSphere. The projects Ms. Brook utilized from KidSphere or other listserves on the Internet typically were not long, involved projects such as Flamingowatch or Kobe. Yet, they could be integrated into curricular units and typically had a short-term focus for the class. One project that Ms. Brook utilized very briefly was the 1995 Iditarod sled dog race. I include in this chapter a description of the Iditarod project and how it corresponded to Ms. Brook's science curriculum. I also include sample Internet messages that provide a window into what this project looked like in the classroom.

The life span of this KidSphere project was about ten days, or the length of the Iditarod sled dog race in Alaska. At the time of the race, Ms. Brook and her class were reading a Scott O'Dell novel called *Black Star Bright Dawn* which was about a very young Native American girl who raced in the Iditarod to honor her sick father. The plot revolved around the adventures and lessons learned while racing in the Iditarod. To supplement this literature unit, Ms. Brook cruised the Internet and found two sources of useful information. First, there was a file which contained color photographs of past Iditarods that students could access, download, and exhibit on the bulletin board. These graphics files also included a detailed map of Alaska showing the route of the Iditarod. Thus, students were able to see some of the regions of Alaska and compare them to the descriptions of the Alaskan wilderness as they were portrayed in O'Dell's novel. Ms. Brook also supplemented this unit with a short video of Susan Butcher, one of the most famous Iditarod mushers. This integration of different resources reflects Ms. Brook's views on interdisciplinary curriculum and her feeling that thematic, interdisciplinary science curriculum best meets the needs of her students (Roberts and Kellough, 1996).

The Iditarod listserv in KidSphere was typical of these types of technology events in that several people from different locations in the world were monitoring the race's progress, and then supplying information about the race over the Internet. The interesting feature of this type of supplemental curricular material is that students may receive information about a particular subject in real-time, that is, as it is happening. Thus, much information they deal with is at least a day in advance of what the news media report. Teachers across the world who wanted to could monitor the race and relate it to their curriculum, be it science, social studies, literature, or a thematic, interdisciplinary unit. In the case of the Iditarod, school teachers in Grayling, Alaska, one of the overnight check point stations for mushers were sending daily reports to KidSphere on race standing, condition of the mushers and dogs, and various aspects of the race. The following message from Grayling was downloaded by Ms. Brook:

> Hi Teachers,
>
> I know that a number of you are following the Iditarod and I thought you might enjoy these personal reports that are coming on the AT & T Learning network from teachers who are in Grayling, Alaska and reporting as the mushers go through their town.
>
> Margaret
> mriel@weber.ucsd.edu
> Margaret Riel, Ph.D.
> InterLearn
> 943 San Dieguito Drive
> Encinitas, CA 92024

This type of message gives the name and address of a contact person for those teachers or students seeking more information about the subject. Some teachers want to use the Internet, but frequently have little idea of how the information they find might be utilized (Draina, 1994; Becker, 1994). The following Iditarod message, written on March 14, 1995 is typical of many exchanges one will find on the Internet and its language suggests how teachers may make connections between messages and their curricula.

> Please excuse me for asking about this. I had noticed a lively discussion about the Iditarod on this list, but I ignored it because I had no real use for the information.

Well, one of our language arts teachers sent a student to me to see if I could get any information about the current race. It happens they are studying "Call of the Wild" and are using the race as a focus. If anyone out there can update me as to the sites to look for this type of info it would impress all sorts of people who are interested in the net but are afraid it is too "nerdy."

Please reply to Jim Egan
jegan@oboe.aix.calpoly.edu

In this message, the teacher's wish to supplement the study of The Call of the Wild with up-to-date information from Alaska about the Iditarod is similar to Ms. Brook's strategy in using it to supplement her language arts novel. This curricular connection is obvious on one level, but presents the classic dilemma that teachers face in their use of the Internet; there are literally thousands of such opportunities weekly if one chooses to explore them all. Thus, even if the teacher is confident and adept at cruising the Internet for supplemental curricular material, which ones to choose, how to utilize them, etc. are still important curricular issues.

Because of the class' reading of Black Star Bright Dawn, Ms. Brook decided to monitor the Iditarod in order to motivate her children and increase their knowledge of the geography and current events in a region described in the book. To begin, Ms. Brook put a large National Geographic map of Alaska on the bulletin board, posting the race's starting point with a plastic pin. Each day, Ms. Brook and her class would read and discuss the Iditarod messages from KidSphere and place a plastic pin on each day's check point location, thus tracking the race on a daily basis. Ms. Brook and her class were able to monitor the race's progress by reading Internet messages daily from Grayling. Following is one of the very descriptive messages that originated from a teacher in Grayling, Alaska.

First musher Doug Swingley arrived in Grayling at about 1:00pm, Friday, March 10, 1995. He will be followed by Martin Buser in about 20 minutes. His dogs came in wearing booties and looking great. He was checked into Grayling by our local checker Dean Painter. Painter ran the Iditarod a few years ago. A week ago he finished second in the Yukon 200.

The local checkers have been busy all morning hauling the straw and food over to the village hall (kashim). The mushers will be getting water and showering at the school if necessary.

> The first item of business for the mushers is to break out the 50 pound bales of straw that are wrapped in red plastic and spread it down for the dogs. The spectators can tell that the dogs know the routine, because they circle around in the straw, make a little nest for themselves and curl up to sleep. The next function is to prepare food for the dogs. The mushers always take care of the animals before they even consider their own comfort.
>
> I notice that the equipment, sleds, etc. are getting more sophisticated. Swingley even has a seat on his sled. One reason is to rest the legs and the other is to lower the musher's body to make the team wind resistant.
>
> The Yukon is greeting the mushers with a strong eastern wind and a wind chill factor of about -35F. The skies are still bright blue and the sun is putting on a great show.
>
> Swingley is in the race to win. He didn't even stop to have the traditional gourmet meal in Anvik. This meal is awarded the first musher to reach the Yukon.
>
> School children and community members braved the chilly winds in their martin hats and skin boots in order to welcome the first musher to Grayling.
>
> UPDATE - Martin Buser just arrived in Grayling.
>
> I'm heading back out to take some more pictures.
>
> Phyllis J. Kardos
> P.O. Box 90
> Grayling, Alaska 99590

In many of these messages, the teachers report on interviewing mushers, and observations they made about the sled dog teams, their physical condition, etc., thus giving readers an "up close and personal" account of the race. Following is an excerpt that contains content that could easily be adapted to science curricula:

> I just spoke with musher Pat Donly. She has participated in six Iditarods. It is a 'mental and spiritual challenge' for her. She is pleased that the vets have told her that her dogs are 'in the best shape of any of the teams.' She was concerned about the temperature. She even commented that she is a little scared about taking off in the cold. It got down to -30F last night and probably will again tonight. She was going to pack up and leave in about two hours.

In this passage, the author described the effects of severe climatic conditions, and her anxiety about prolonged exposure to such conditions. This concept would be particularly appropriate to science curriculum. Another message that relateed nicely to science subject matter and also is very descriptive follows below:

> One thing about this race, it's not like the Indy 500 where everything depends on each second of the clock and tremendous speed. The Iditarod is almost relaxing to watch. The steady smooth pace of the dogs. The gentleness in the way the mushers handle their dogs. DeeDee Jonrowe talks to her dogs like they are babies. I guess they are to her. The mushers are very meticulous about their equipment, and dogs especially. One has to realize where these mushers and their teams are and the severity of the weather at times, and even how fast the weather can change. This year the weather has cooperated beautifully. No major storms, but now the cold, which the mushers do dread. It must be a lonely feeling out there in the middle of the Alaska wilderness. Even when you know the world is watching your every move, it is still a lonely place.

Thus, very descriptive and evocative messages came across the Internet into the classrooms of America and the world. Unfortunately for Ms. Brook and others following the race, technical difficulties in Alaska cut short the reporting to KidSphere. Before any significant unit could be based on Iditarod, the information flow stopped. I described in detail some of the technical difficulties encountered in the Flamingowatch unit, and the Iditarod-type projects are frequently plagued by being unpredictable and at times unreliable.

Another "problem" with using KidSphere and forums like it is the sheer volume of messages received each day. Literally hundreds of messages may flood one's account each day, forcing quick decisions about what material to read, and which messages to delete. Ms. Brook solved this problem in part by using a manager program which allowed her to sort the messages according to key words and topics. Thus, she could quickly scan for Iditarod messages and delete the rest.

Summary of Findings

We do not know how future technologies will effect science curriculum. In this chapter, I described how Ms. Brook utilized current instructional technology to effect a technology-rich curriculum. Although each technology episode described in this section had a different focus, one technological thread linked all three: using the Internet to access information and telecommunicate with others. Davis (1994) described the power of telecommunications in allowing students to "ignore the walls of the classroom and make direct contact with others across the world."

In this section, I described and contrasted three types of technology-rich science units. Flamingowatch was commercially produced by Turner Active Learning and with a curriculum guide of over three hundred pages, was comprehensive in scope. As well as an extensive curriculum guide, the unit included supplemental technology resources such as a database on East Africa, computer graphics, and on-line forums. As Ms. Brook described it, this project was primarily teacher-directed in that students did not have a direct role in deciding to participate in the unit. Within the unit, however, students made their own decisions regarding the direction of their research projects.

In contrast, the Kobe project was almost entirely student-directed. Kobe was a real-time, current events-based technology project. Combined with other resources, Ms. Brook's students utilized the Internet to gain inside perspectives on the Kobe earthquake. This particular project would not have occurred had the earthquake itself not occurred.

Finally, the Iditarod project was an Internet project based on a yearly, planned event. The essence of the project was students' use of the Internet to access up-to-the-hour information from rural Alaska to supplement their classroom resources. The description of the Iditarod project in this section included samples of downloaded Internet messages.

Flamingowatch

Each technology episode was fully described in this section. Flamingowatch was unique among current technology-rich curricula due to its worldwide audience, its three-day real-time fieldtrips, and its interactivity. Both Ms. Brook and her students described the motivational aspect of the interactivity of Flamingowatch. Students were able to ask questions of the experts in the Kenyan field in real time, communicate with colleagues through AOL immediately after each fieldtrip, and follow the progress of Kenyan school children as they traveled through Kenya's game parks and reserves. Flamingowatch's interactivity, interdisciplinary curriculum, and emphasis on research and problem solving could be the type of curriculum that is on the vanguard of the development of global classrooms. Davis (1994) argued that given access to technology-rich curriculum, students could work directly with peers throughout the world, a perspective shared by Ms. Brook. Itzkan (1994) also argued that this type of international collaboration might lead to "global citizens" whose projects may transcend school work to become vehicles for the exercise of citizenship. This argument is in close concert with Ms. Brook's views on scientific inquiry which are described in chapter 7.

Although the fieldtrips lasted only three consecutive days, the thematic, interdisciplinary nature of the curriculum could be utilized for at least a semester if teachers and students so desired. MEGOSE argues for science curriculum to become more interdisciplinary, and Benchmarks describes different examples of interdisciplinary curriculum (MDE, 1991; AAAS, 1993). In this regard, Flamingowatch is both thematic, with each fieldtrip focused on a different theme, and interdisciplinary, with activities that combine science, social studies, language arts, problem solving, and study skills.

Implementation of Flamingowatch engaged Ms. Brook's students in activities that corresponded closely to the MEGOSE dimensions of scientific literacy (MDE, 1991). Document analysis of the Tools and Resources included in the Flamingowatch curriculum guide illustrated the close link of Flamingowatch to using, constructing, and reflecting on scientific knowledge, STS issues, and use of instructional technology in scientific inquiry. The themes and goals of Flamingowatch were based on competencies outlined in Benchmarks (AAAS, 1993) and therefore, Flamingowatch was closely related to both MEGOSE and Benchmarks. For example, the MEGOSE dimensions of scientific literacy and related Flamingowatch activities were reported in Tables 12, 13, and 14. Participation in Flamingowatch activities required students frequently to explain, describe, and predict vis-a-vis scientific concepts and issues as well as design solutions to problems and issues identified in their scientific inquiry.

The authors of Flamingowatch described the entire curriculum as **problem centered**. This problem centered approach to science curriculum closely fit with Ms. Brook's approach to scientific inquiry which I describe fully in chapter 7. Palincsar et al., (1993), Meier et al., (1996), and the AAAS (1993) all describe the development of problem solving skills as integral to achieving scientific literacy. This study highlights Ms. Brook's integration of instructional technology in developing students' problem solving and inquiry skills.

Ms. Brook indicated the difficulty of trying to implement curricula related to students' real world when she stated:

> Application of something that is real is one of the hardest things that a teacher tries to find. How do you create a learning situation that is real to the students?

While advocating connecting learning to students' real lives, MEGOSE (MDE, 1991) also recognizes the difficulty of representing some science concepts in a real-world context, and suggests that in such cases, real-world representations might include pictures, diagrams, audio visual media, etc. One of the strengths of Flamingowatch is that teachers do not have to "find" their own real world curriculum: in Flamingowatch it is ready-made. But is it real world to most students? This study describes Ms. Brook's view that Flamingowatch is real world due to its focus on the live television broadcasts and students' ability to interact with colleagues in East Africa in real-time. Also, as Itzkan (1994) and Davis (1994) argued, students and teachers are utilizing instructional technologies more and more to extend their real world to a global audience. Probably the strongest finding in this section is the rich description of what classroom interactions look like while implementing a technology-rich curriculum such as Flamingowatch.

In sum, Flamingowatch fostered students' pursuit of scientific literacy and inquiry. It was technology-rich in that students utilized a variety of instructional technology while participating in the project. In Ms. Brook's view, the project also fostered inquiry in a real-world context, an important goal of MEGOSE (MDE, 1991).

How important was the use of instructional technology in implementing Flamingowatch? Both Ms. Brook and her students described technology as being the essence of the project. Ms. Brook specified that the technological nature of the project was a HUGE (her emphasis) part of it. Technology made the live presentations possible. The CNN video clips, AOL discussion forums, and electronic curricular resources all contributed to the technology-richness of Flamingowatch. In essence, Flamingowatch would have been impossible to achieve without utilizing instructional technology.

Ms. Brook and her colleagues also utilized instructional technology to collaboratively evaluate and transform the Flamingowatch curriculum into a unit that met their science goals and objectives. Collaboration among teachers and specifically collaborative unit planning is a highly desirable but seldom achieved aspect of teaching (Sanche et al., 1993; Roberts et al., 1996; Brown and Logan, 1993; NRC, 1996; Lortie, 1975). As a result of their collaboration, the four teachers who participated in this project divided their students into research teams. Each team researched an East African animal and through utilizing instructional technology, were able to conduct a very professional, live video conference to share their research findings, a skill advocated by MEGOSE (MDE, 1991), the NSES (NRC, 1996), and Grejda and Smith (1994). As Ms. Brook stated, technology facilitated this collaboration and inquiry, and the project would have been impossible to achieve without it. The models of scientific inquiry reviewed in this study described the importance of students sharing the findings of their inquiries (NRC, 1996; AAAS, 1993).

In general, the Turner Active Learning curricular units are technology-rich, and require the use of various instructional technologies in their implementation. Ms. Brook characterized Flamingowatch as "unique" due to the brilliant audio and video aspects of the live fieldtrips. However, she also described the problematic nature of such technology -rich units. When utilizing instructional technology, glitches in the technology often occur, and teachers wishing to implement technology-rich units such as Flamingowatch should be aware that technological problems do occur. This study found Ms. Brook to be aware of such problems, and willing to troubleshoot her way through the technological problems as they occurred, chalking them up to learning experiences which would better prepare her for the next technology project. Along with technological glitches that inevitably occur, Ms. Brook also raised the issue of public relations and funding issues regarding integration of technology across the curriculum. Sternberg and Horvath (1995) argued that expert teachers may have to know how to package and sell curricular innovations to fellow teachers, parents, and administrators. In an era of shrinking budgets, which Ms. Brook had to deal with at Jefferson, expert teachers need to know how to "work the system" to obtain needed services or levels of support from the administration and the community (Sternberg and Horvath, 1995). While Grejda and Smith (1994) and others argue for widespread technological literacy among teachers, teachers and administrators feel the financial pinch when it comes to funding and public support for technology. Many people view technology as an "add on" rather than an integral component of curriculum. As Ms. Brook stated: "You still have to sell it over and over and over to administrators, and so many people still perceive technology as a frill in the budget."

Kobe and Iditarod

Like Flamingowatch, the Kobe project focused on both science content and social issues (Bybee, 1993). A student-conceived project, Kobe involved students in service to others, what Bybee (1993) described as promoting a high regard for the rest of humankind. Due to the emotional level of the purpose and content of the Kobe project, it epitomized learning in a real-world context. Bybee (1993), Yager (1990; 1993) and others describe the benefits of STS curricula, and studying social issues in a global context. By utilizing instructional technology, Ms. Brook's students were able to solve real problems while keeping abreast of the scientific and social consequences of the Kobe earthquake through the eyes of real people in Japan. Using instructional technology to pursue this type of inquiry has tremendous implications for science and other curricula. As Ms. Brook stated about the project: "It for sure was student initiated." The NSES (NRC, 1996) recommend that teachers work with the school and community at large in effecting their science programs. In the Kobe project, Ms. Brook's students, through their fund raising efforts, involved other students, teachers, and administrators at Jefferson School. Fund raising and communication quickly extended to the community at large, many parents of Jefferson students, the local news media, and the local chapter of the Red Cross. Again, the utilization of instructional technology facilitated the learning in this project by fostering direct lines of communication between Ms. Brook's classroom and people throughout Japan. Ms. Brook argued that the use of technology enabled her students to make "a personal connection on a world basis," which contributed to their becoming global citizens. Ms. Brook also hinted at the ability of technology to motivate students to learn when she stated:

> That's probably the best reason to go with the technology-related projects, like Kobe, because it was happening, and it was real to all of us. I didn't have to generate interest in earthquakes - it was there! Hum?! So think about it.

Upon seeing video of the Kobe earthquake, Ms. Brook's students quickly identified the problem: "We can help them." Thus, this scientific and social inquiry was born from a real need, and had authentic purpose. Students' use of instructional technology played a key role in helping real people, and was consistent with the benefits of educational telecommunications as described by Stahlhut (1994) and Rush (1993). In fact, by the projects' end, Ms. Brook's students had demonstrated their mastery of many of the characteristics of technological literacy described by Grejda and Smith (1994). Through implementing these technology episodes, Ms. Brook specifically demonstrated her knowledge and ability of two principles of technological literacy described by Grejda and Smith:

> f) evaluate, select, and integrate computer technology-based instruction in the curriculum of one's subject area(s) and or grade level(s);
>
> g) demonstrate knowledge of multimedia, hypermedia, and telecommunications activities to support instruction (Grejda and Smith, 1994, p. 779).

Teachers wishing to develop projects such as Kobe should realize that Kobe wasn't planned; it developed as a result of a current event. Thus, curricular flexibility is a prerequisite for those teachers planning to utilize current events to supplement their curriculum (whether or not they utilize instructional technology to do so). Ms. Brook was willing to put her lesson plans on the back burner in order to allow students to pursue the Kobe project. The flexibility Ms. Brook demonstrated throughout the Kobe project is consistent with the NSES (NRC, 1996) science teaching standards and is more fully described in chapter five.

Similarly, the Iditarod project illustrates for teachers wishing to integrate instructional technology into their curriculum some positive and negative aspects of technology use. A so-called Internet project, Iditarod was typical of the many opportunities teachers have to supplement their curricula with technology projects. Iditarod provided useful, interesting, and extremely current information to students. It lent itself to its incorporation into an interdisciplinary unit (Roberts and Kellough, 1996). However, one could also say about Iditarod: "It was good while it lasted." Such projects are a curricular gamble. In this case, the Internet messages describing the sled dog race were halted prematurely. Thus, students were unable to follow the entire race through utilizing the Internet. While having tremendous curricular potential, Internet-based projects are also susceptible to the technical difficulties described elsewhere in this study. Thus, teachers who plan Internet-based projects should also have a back-up plan in the event technical difficulties occur. Key to this planning is whether teachers view the Internet project as central to the unit or supplemental to the unit. My findings indicate that Ms. Brook used Iditarod in a supplemental fashion, while utilizing several other resources to study the main topic.

These findings about the technology-rich curriculum implemented by Ms. Brook have implications about the role of the teacher in a technology-rich classroom (Dwyer et al., 1991). In chapter eight, I describe Ms. Brook as an exemplary technology-using science teacher and provide an analysis of her teaching framed by the NSES (NRC, 1996) and other references.

CHAPTER 7

TEACHER KNOWLEDGE, VALUES, AND BELIEFS ABOUT SCIENTIFIC INQUIRY

Research question 7:
How does this elementary teacher utilize instructional technology to promote scientific inquiry?

Relevant Data, Analysis, and Interpretation

In chapter two, I reviewed what I believe to be a traditional view of scientific inquiry as described in the NSES. The purpose of this section is to describe how Ms. Brook utilized instructional technology to accomplish scientific inquiry. I contrast the NSES and Benchmarks views of scientific inquiry with scientific inquiry accomplished through the implementation of a technology-rich science curriculum; describe what students do in a technology-rich inquiry; and describe students' perspectives on working in a technology-rich classroom.

In chapter one, I provided a rationale for scientific literacy that was based on the idea that Americans now live in a technology-driven, complex society that has become more and more global in nature. For example, the increasing media attention to the spread of infectious viruses around the world indicates clearly that health threats originating in African jungles can appear in America in a matter of hours. As Viau (1994) put it:

> As the world becomes a global village, all peoples must face the same problems: pollution in the environment, surging populations, shortages of food, water, and materials, collapsing ecosystems. These problems are seen from a plethora of perspectives: cultural and religious values influence how these problems are perceived and determine the acceptability of possible solutions (p. 7).

To deal with such issues, Americans need to be scientifically literate, and according to SFAA (1990), most Americans are not scientifically literate.

Benchmarks for Science Literacy

How do Americans become scientifically literate? According to the science education literature (SFAA, 1990; 1993; NRC, 1996; MDE, 1991), scientific literacy should begin in the early school years and be the primary goal of all school science programs. The NSES (NRC, 1996) argue that scientific literacy is achieved when students pursue scientific inquiry in order to make sense of their natural world. Benchmarks (AAAS, 1993), which is currently framing many K-12 schools' science curricula, describes scientific inquiry as a complex process, much more complex than the inquiry paradigm described in most science textbooks. It involves more than "doing experiments" and "making observations" (AAAS, 1993; McComas, 1996). It involves a complex combination of imagination and inventiveness with logical thinking and empirical evidence (AAAS, 1993). Benchmarks describes several aspects of traditional scientific inquiry that are also described in the NSES, including: design more time for authentic student investigations and assist students in designing investigations that approximate "sound science." The benchmarks for scientific inquiry for students in grades three through five focus on students knowing about different types of investigations, the procedures of conducting an investigation, how scientists develop explanations about observations, and the role of evidence in making logical arguments (AAAS, 1993). Following is a sample benchmark for scientific inquiry for grades three through five:

> Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments. Investigations can focus on physical, biological, and social questions. (p. 11)

In describing the process of science, Benchmarks (AAAS, 1993) concurs with the NSES (NRC, 1996) and DeBoer (1991) that scientific methodology should not be taught as a lock-step series of procedures that lead to new discoveries, but rather as a process of inquiry that has many variations. Also, students in grades three through five are not generally capable of understanding such concepts as controlled variables and scientific theory (AAAS, 1993; DeBoer, 1991). Thus, educators should be cognizant of the limitations in teaching certain aspects of scientific inquiry to primary-aged students.

In chapter two, I described the abilities for scientific inquiry listed in Content Standard A: Science as Inquiry (NRC, 1996), which are similar to those described by Benchmarks (AAAS, 1993). The abilities in Content Standard A (NRC, 1996) primarily focus on student participation in scientific investigations and engaging in scientific thinking. DeBoer (1991) described three historical reasons for teaching scientific thinking to students. During the nineteenth century, it was thought that thinking in a disciplined, rational way would strengthen the overall intellect. Second, it was argued that scientific thinking could be transferred to nonscientific content, thereby making people more effective thinkers in their everyday lives. Third, those who would become future scientists needed to be initiated into thinking scientifically as early as possible. Thus far, the concepts of studying science to develop increased general mental capacity, and transfer of learning to everyday lives are not supported by evidence. One of the most important conclusions of the research on higher order thinking skills is that transfer of those skills from one area to another does not occur automatically (Hamm, 1992). The research suggests that if teachers are aware of and actively promote subject matter generalizations, transfer to real world situation will be more likely (Tobin and Fraser, 1989). The third argument for scientific thinking contrasts with today's goals for science education (MEGOSE, 1991). The goal of school science should not be to develop millions of "little scientists," but rather to promote scientific literacy in all students. Thus, the ability to think about scientific problems is pertinent to that pursuit.

National Science Education Standards

Scientific inquiry is the process scientists and others use to solve problems and answer questions (Meier et al., 1996). In the NSES view of scientific inquiry, a prescribed "scientific method" is not advocated. The NSES argue that students' questions might develop from many sources, and not as a result of a carefully controlled sequential approach to studying science. As I stated in chapter two, the NSES describe scientific inquiry as: "asking a single question, completing an investigation, answering the question, and presenting the results to others" (NRC, 1996, p. 122). The NSES qualify this process by arguing that K-4 students may have difficulty with certain aspects of investigation such as testing ideas and using logic and evidence to formulate explanations (NRC, 1996). If that is true, it seems then that many fourth grade students would be limited in their ability to pursue full scientific inquiry as described in the NSES Content Standards.

As an example of appropriate scientific inquiry, the NSES present a vignette called "Willie the Hamster." In this vignette, the teacher has encouraged her students to engage in investigations that they are interested in. She has taught her students some of the components of scientific inquiry such as considering alternate explanations, evaluating evidence, and designing simple investigations. In the class investigation, Student 1 notices that the level of water in the watering can drops every night. Since none of the children in the class took the water, the class hypothesizes that Willie the hamster must be leaving his cage at night to drink the water. Student 2 designs a test to see if Willie does in fact leave his cage at night to drink the water. The test results show he does not, but the students still have questions about the results. The teacher asks "How can you be sure?" The students then devise another test to determine whether Willie leaves his cage at night to drink water from the watering can. The results show he does not, yet the water level in the can continues to drop. Based on these results, the students dismiss the idea that Willie the hamster is responsible for the disappearing water.

At this point, the teacher begins to work with the class on the concept of evaporation. She suggests they place a container of water on the window ledge and measure and record changes in the water level each day. Students collected measurements and developed a bar graph showing the daily water loss through evaporation. Because the evaporation rates were uneven, students suggested air temperature might affect evaporation rates. The students continued to experiment by varying the container size, blowing air over the water, etc.

In this vignette, students were curious about a problem in their classroom. They worked together to design a series of experiments to try to solve the problem. According to the NSES, this process exemplifies scientific inquiry.

Like Benchmarks (AAAS, 1993), the NSES Content Standards delineate what students should know at specific grade levels. For example, Content Standard C: Life Science, states that K-4 students should develop understanding about the characteristics of organisms, life cycles of organisms, and organisms and their environments (NRC, 1996). The closest correlate from Benchmarks is the chapter on "The Living Environment." This chapter delineates benchmarks on the following topics: diversity of life, heredity, cells, interdependence of life, flow of matter and energy, and evolution of life (AAAS, 1993). In both the NSES and Benchmarks, the process of scientific inquiry is embedded in understanding science content through inquiry. In NSES, the subject matter is represented in the traditional disciplines of life, earth, and physical science. Also included is a standard on Science and Technology (NRC, 1996). In Benchmarks, science content is represented thematically with chapters such as: The Nature of Science, The Designed World, Human Society, and Historical Perspectives. Thus, there are similarities and differences in the way scientific inquiry is presented in Benchmarks and the NSES, but the concept of scientific inquiry is very similar in its definition in both documents.

In the NSES Content Standard C, how would students develop understanding about biological concepts? The authors of the NSES argue that elementary children develop their understanding of biological concepts through "direct experience" with living things. Children generate questions about their natural environment from their general sense of wonder (NRC, 1996). From those questions, students design activities and investigations that help them develop understanding. At the K-4 level, the focus of biological study should be on the primary association of organisms with their environments with a secondary focus on the concept of dependence for survival (NRC, 1996).

MEGOSE (MDE, 1991) strongly advocates a connection of science curriculum to students' real lives. The analysis in chapter 5 indicated that Ms. Brook also advocated the real-world connection to students' lives. Ms. Brook's view on how to achieve that real-world connection, however, appears to be fundamentally different from that described in the NSES and MEGOSE. Regarding the concept of "real-world," the NSES states:

> Because the child's world at grades K-4 is closely associated with the home, school, and immediate environment, the study of organisms should include observations and interactions within the natural world of the child (p. 128)

In this passage, the NSES views the child's real world as being their immediate, local environment. Through utilizing instructional technology Ms. Brook developed a new paradigm for WHAT students' real world could be. In chapter 5, she described real world as "anywhere they can travel electronically." Thus, Ms. Brook's vision of what students' real world could be is greatly expanded compared to the NSES view of the real world. Below I contrast Ms. Brook's paradigm of scientific inquiry based on instructional technology with that of the NSES and Benchmarks, both described above.

Ms. Brook's View of Scientific Inquiry: A New Paradigm

Kuhn (1970) introduced the term paradigm to help explain how new perspectives emerge, and argued that new perspectives are sometimes vigorously resisted. The term paradigm comes from the Greek word paradigma, meaning to "pattern, example, or model" (Shapiro, 1994, p. 6). Kuhn used the phrase "paradigm shift" to describe what happens when a new insight offers explanation of events that were previously explained in another way, or were only partially explained. Paradigm shifts in science education are usually painful, requiring people to change methodology or pedagogy. Kuhn alluded to the difficulty of a paradigm shift by saying that it takes about twenty-five years to achieve one - because the original defenders have to die off (Kay, 1991). Gallagher's (1993) research on helping science teachers make the paradigm shift to constructivist practice described the difficulty of shifting paradigms, but provided evidence that it could be done. Like Gallagher, Dwyer et al., (1991) described a successful paradigm shift made by teachers who participated in the Apple Classrooms of Tomorrow (ACOT) study:

> Today, the staff of ACOT's classrooms are more disposed to view learning as an active, creative, and socially interactive process than they were when they entered the program. Knowledge is now held more as something children must construct and less like something that can be transferred intact. The nature of these teachers' classrooms, the permissions they grant their students, and their own instructional behaviors demonstrate this shift in action. (p. 50)

The contrast of the concepts of students' real world described above, combined with how scientific inquiry could be achieved through utilizing instructional technology is the crux of the new paradigm of scientific inquiry I describe in this section. Having said that, I argue that Ms. Brook's view of students' real world is not exclusive of the NSES view: Ms. Brook also utilized the classroom, school grounds, and local community to connect the curriculum to students' real lives. Nor is the NSES view of scientific inquiry to be discounted. Viau (1994), while promoting the technological paradigm, also argues for the value of traditional scientific method when she states:

> The scientific process, with its emphasis on accurate observation, independent verification, and rational interpretation has focused Western minds on trying to see something *as it functions and as it is* while screening out much of the context as irrelevant. This disciplined concentration is a very powerful way to process information; it has given us taxonomies, flow charts, graphs, and such concepts as evolution, cyclical natural processes, and ecological webs. Science gives us powerful tools for focusing on specific problems, seeking relevant data, and observing events under controlled conditions. (p. 10)

Thus, traditional scientific inquiry remains a valuable ability for students to have, but it is not, Viau argued, the only inquiry model students should possess as they make sense of their world. The global view of students' real world and their use of instructional technology as a primary tool of inquiry is the paradigm shift that takes Ms. Brook beyond the NSES view of scientific inquiry. Ziman (1994) argues similarly that STS education goes beyond what is commonly accepted as "valid science," by saying that the purpose of

STS is to enhance and complement traditional science. In speaking about the traditional scientific view, Ziman (1994) states: "The fundamental weakness of valid science as it is usually taught is not what it says about the world, but what it leaves unsaid" (p. 22). Likewise, Ms. Brook's view of scientific inquiry goes beyond that of what Ziman refers to as valid science. Viau (1994) argues for preparing students who are skilled in the scientific inquiry paradigm Ms. Brook is teaching her students. Viau states:

> We need minds that can see perspectives other than their own, that can compromise without losing sight of larger objectives, that can translate ideas from one culture into the argot of another, that can move models of solutions into new areas of application. These skills have always been in short supply. (p. 7)

In describing the role technology will play in students' literacy skills, Hill (1992) argued that teachers need to prepare students for the literacy of the world they will inherit, not for the literacy that today's teachers grew up in. Accordingly, teachers need to acquire technical skills in telecomunications and other technologies in order to promote scientific inquiry. To pursue scientific inquiry in this way, it is critical that teachers understand the importance of accessing and processing information as a necessary skill for the 21st century (Rush, 1993).

In chapter three, I briefly described Ms. Brook's classroom vis-a-vis the instructional technology available to students. Technology-rich classrooms are described in the literature as on a continuum with the amount and type of instructional technology at varying levels (Dwyer et al., 1990; Solomon, 1993; Novelli, 1993; Bruder, 1993; and Bennett and King, 1991). I would describe Ms. Brook's classroom as middle-of-the-road technology-wise in comparison to other elementary classrooms. The cable television video hook-up in Mr. Santo's room, and co-utilized by Ms. Brook, allowed for the collaboration with Lincoln School in the Flamingowatch project, and that level of instructional technology is unusual in elementary classrooms. Although her classroom had three computers, that is a deceptive number because two were owned by Ms. Brook. She felt she needed to bring her own equipment into the classroom in order to have the "critical mass" necessary to do the type of technology-rich curriculum projects she favored (Cuban, 1984). Without Ms. Brook's personal computers, her classroom would have only one computer. In contrast, on the other end of the continuum, are schools such as the Saturn School. The Saturn School is a technology-rich elementary school referred to as the "School of Tomorrow" (Bennett and King, 1991). The school is void of textbooks, and rich in multimedia technology. The school is equipped with Integrated Learning Systems, videodisc presentation equipment, and computers connected to videodiscs. While Ms. Brook's classroom lacked the variety of instructional technology of the Saturn School, she did possess the critical pieces of hardware that facilitated the implementation of the technology-rich curriculum: the private phone line and modem. With budgetary support from the administration, Ms. Brook and her students could engage in on-line inquiry every day.

The technology-rich curriculum Ms. Brook utilized in teaching science was richly described in chapter 6. While the Flamingowatch, Kobe, and Iditarod projects all had different curricular characteristics, each allowed students to pursue scientific inquiry through utilizing instructional technology. In contrast to the type of scientific inquiry described in the NSES, Ms. Brook's pursuit of inquiry focused on students' use of instructional technology to research issues, answer questions, or address social issues. These issues included both local (wetlands) and global (Kobe) issues. In order for students to be able to address those issues, they need "the skills necessary to survive in a constantly changing environment that is being predicted for the 21st century". (Hill, 1992, p. 29) Critical aspects of this form of scientific inquiry include: how children utilize instructional technology to access information and the sharing and reporting of that information through collaboration. Communication with others outside the classroom is tremendously motivating for both teacher and students, and this justifies the extra time and effort required to implement a technology-rich curriculum (Davis, 1994).

Novelli (1993) described technology-rich classrooms and curricula as being focused on student-centered learning and cooperation. Students utilize a variety of instructional technologies to solve problems. Instructional technology is an effective tool to integrate curriculum and promote inquiry (Novelli, 1993). For example, Novelli (1993) described an elementary teacher who used the National Geographic Kids Network to study Shaker communities in New Hampshire. The Network allowed students to gain cultural understanding of Shaker communities from the insiders' perspective. In their research on project-based, technology-rich science classrooms, Jackson et al., (1994) argued that microcomputer and telecommunications technologies have the potential to promote meaningful and memorable educational experiences for upper-elementary students. The National Geographic Kids network is one of the most well-established success stories in promoting technology-based inquiry (Jackson et al., 1994). Levak et al., (1993) argued the importance of students thinking globally in order to identify choices, reach judgments, and make decisions in their local community. Thus, teachers and students, armed with a critical mass of instructional technology, can pursue scientific and other types of inquiry by utilizing instructional technology to access global resources. In doing so, students become what Itzkan (1994) referred to as "global citizens."

In pursuing scientific inquiry with students, Ms. Brook heavily utilized instructional technology, but also utilized a variety of other resources. Given Ms. Brook's visualization of curriculum as being integrated, and given her frequent use of the Internet to supplement curricula, it is not surprising that a variety of resources would be brought to bear on curricular issues. I asked Ms. Brook to comment on the types of resources she used in the Flamingowatch project, including the National Geographic issue containing the Great Rift Valley article I noticed on her desk:

> (incredulous that I noticed that on her desk) You see that stuff? They can't read it, Greg! (laughing) We can, but a 9 year old can't read that script. But the pictures are just lush. So, how do you integrate it? I didn't teach a lesson on it [the magazine] but it was one more piece of material [curricular] available and the *Zoo Books* were just age appropriate and perfect for the Flamingowatch unit and this grade level. So, some kids were looking at the

> *National Geographic* and others were looking at the *Zoo Books* and every kid went to the library and brought those resources in too so, it's just a matter of resources........ and that's a resource that a lot of kids have at home too so it serves two purposes: 1) for the specific topic of the Great Rift Valley and 2) the more times a kid is aware of how many resources they have at their fingertips at home, they are more inclined to use the resources because they can use them at convenient times because they're at home. That's not always obvious to a child, so home resources like National Geographic, let kids remember one more time that they can be learning stuff outside of school time as well as in school........ I want all the learning stuff to be really spontaneous too, and I'll even plan lessons so that they appear to be spontaneous so that the kids see that learning doesn't stop, it's a lifelong process....

In this passage, Ms. Brook described the value of resources such as National Geographic and Zoo Books to projects such as Flamingowatch. While she did not use the National Geographic article in an official way, she acknowledged that some students looked at it. She also emphasized the importance of students using resources such as books and magazines at home. She felt using resources in this way reinforced the importance of learning in the home, and that learning is a "life-long process."

Other resources utilized in the Flamingowatch project are carefully outlined and described in chapter 6. However, in all of the curricular projects I observed, Ms. Brook typically utilized a variety of resources in their implementation. The following chart illustrates the point.

Table 17 Resources Utilized in Curriculum Implementation

Curricular Unit	Resource
Flamingowatch, Kobe, Iditarod	Reference books
Flamingowatch, Kobe, Iditarod	Literature
Flamingowatch, Kobe	Guest speaker (s)
Flamingowatch	National Geographic
Flamingowatch	Pictorial magazine (e.g., Zoo Books)
Flamingowatch, Kobe, Iditarod	Audio visuals
Flamingowatch, Kobe, Iditarod	Multimedia technology
Flamingowatch	Outdoor local resources
Flamingowatch, Kobe, Iditarod	Library resources
Flamingowatch, Kobe	Students' resources

While Ms. Brook utilized a variety of resources in every unit she taught, she was very frustrated at times at having to use traditional resources such as reference books in the school's library. When I posed a question about using reference books, Ms. Brook responded:

> This is one of those things that is actually wrong! These kids are working right now on country reports and we're teaching kids how to use books on the shelf - these hard copy things and the kids - they are actually learning, finding out and writing down incorrect information. I'm not saying that everything in printed material has to be on an electronic format, but for some things, if we teach the kids you can use these materials for this kind of research we're not teaching them the RIGHT (her emphasis) way. Right now this whole country project is a really prime example. To tell Joey to go and find out about Singapore, which he thought was in Malaysia rather than a separate country, the books say that......
>
> I think we're probably getting there if I think what our schools were like 10 years ago, part of our budget included 25 workbooks for each subject - we're not even ordering that stuff anymore, at least in this district, um, I don't think that companies are even producing that stuff anymore. It's going to take teachers a while before they realize what is needed for research. This project is a traditional kind of research project that is done in every school. But how we teach the kids to access information is going to be the issue.
>
> GC: Even your kids are getting to use Encarta and Groliers, and.....
>
> Yes, and using the Internet helps to update the information. Grolier and Encarta, it could replace that hard copy reference on the shelf but what I want is a living document for the kids to get their information (referring to Encarta, etc.). If you wanted to get information today about Bill Clinton, you wouldn't go to hard copy, or maybe not even to a newspaper, you might want to go straight to a current hourly update on the Internet. There are a lot of teachers who don't know that - that there are sources available to get hourly updated information.

In this passage, Ms. Brook acknowledged the importance of using resources to do "traditional kinds of research," as is done in every school. However, she highlighted the main issue as being one of <u>how</u> teachers marshall resources and teach students how to access information in the research process. She stated the importance of using the Internet in this process because it allows one to get up-to-the-hour information on almost any topic. Utilizing instructional technology in this way is consistent with the technological standards described by Grejda and Smith (1994) and is consistent with the type of technological inquiry described by Novelli (1993); Bruder (1993); and Solomon (1993). She also advocated students using what she referred to as the "living document," an electronic encyclopedia. The Groliers and Encarta encyclopedias Ms. Brook mentions are CD-ROM versions of traditional encyclopedias. They are updated yearly, and include thousands of color photographs, graphics, and short movie clips on hundreds of topics. For example, students can not only read about the Civil War, they can also see a short movie clip on the action of the battle, or download maps, pictures, and text via printer. Thus, it is evident Ms. Brook demonstrates a knowledge of multimedia resources to support scientific inquiry through instruction (Grejda and Smith, 1994)

Ms. Brook also revealed in this passage that many teachers are not thinking about using electronic encyclopedias nor the Internet with their students. She stated that many teachers do not know sources are available to get hourly updates on topics. Most elementary teachers have not attained the level of technological literacy needed to promote scientific inquiry consistent with Ms. Brook's new paradigm (AAAS, 1990; Becker, 1992; Grejda and Smith, 1994). Thus, Ms. Brook described her resources of choice, and also briefly commented on teachers' need to become more aware of the electronic resources available to them.

How did Ms. Brook's students respond to utilizing instructional technology in the inquiry process? I include here a short section on students' perspectives on the Flamingowatch project and their beliefs about their use of instructional technology in general. Shapiro (1994) argued the importance of understanding children's thoughts and feelings about science learning because children's early experiences with science are crucial to their development of positive feelings toward science learning. Likewise, how students feel about science in elementary school will influence their interest in pursuing further science study (Shapiro, 1994). The same is true for instructional technology. It is important to understand how students feel about using technology in pursuing scientific inquiry.

Student Perspectives on Flamingowatch

To determine students' perspectives on using instructional technology, I made anecdotal notes from classroom observations, informally discussed technology use with students during projects, and formally interviewed students. To begin our discussion about Flamingowatch, I asked Jackie, Jim, and Vern to describe their impressions of the project.

Jackie: There was a show that we watched every day for three days and we learned a lot about the animals and we learned about how the flamingos eat and how they like where they live and how they migrate and stuff. And we used technology to do the talk shows and we did an animal research project and that had to do with the Flamingowatch because in the Flamingowatch there was like they told about the different lands, different parts of the land, and then we did an animal research on an animal we liked with the Flamingowatch.

Jim: It was a show where someone wanted to know about the Rift Valley and at XYZ Cablevision they thought well, we might be able to go and do a Flamingowatch thing or something and then, or Turner Adventure actually, and they went there and they did a whole show on it so whoever wanted to and has the right equipment could learn about the flamingos and other animals there and the ecosystem and how it works.

Vern: It was a technology project and one you do using computers and through television and through your ability to use different equipment. And I'd also describe it as something that like, um, it's, well...(thinking). It is a project you'd do as a group, cause it wouldn't be as interesting if you just did it by yourself or one other person. You have questions that you don't have the answers to or if others have questions, you may have the answer to it and you can share your ideas with other people and it's just more interesting but, uh, um, with a group and I think it's pretty interesting that we can go from one classroom to another by just using technology..... It was an electronic fieldtrip because, it's electronic, and it's through computers.... (inaudible) and we're watching them, and hearing them, and talking to them, by electronics so I think that's why its called an electronic fieldtrip.

In describing the Flamingowatch project, Jackie described "what we learned." In the passage above, she focused on describing the Flamingowatch project in terms of the science content learned. She mentioned the habitat and migration of flamingos, the geography of the Great Rift Valley, and the animal research projects completed. She briefly mentioned the electronic talk shows and the actual live broadcasts, indicating an understanding of the technology embedded in the project. In response to my questions, she provided a very accurate and succinct overview of the project.

Responding to the same questions, Jim and Vern focused on the technological aspects of the project. Jim indicated that the purpose of the project was to use the "right equipment" in order to learn about flamingos, other animals, and the functioning of the ecosystem. Vern focused strongly on the technological aspects of Flamingowatch, explicitly stating "it was a technology project." He gave an overview of the technology used in the project, describing the role of technology. Vern also expressed the view that the project was more interesting because it was a group project. He reinforced a theme that emerged from the students' perspectives: that collaborating and sharing information were important aspects of their science learning. Thus, Vern described Flamingowatch in a way that was consistent with Kay's (1991) analysis of instructional technology: that by using instructional technology, students are able to develop knowledge of their own collaboratively. This collaboration is also consistent with the MEGOSE (MDE, 1991) dimensions of scientific literacy.

As the summary of students' perspectives on Flamingowatch indicate, their knowledge of how instructional technology contributed to their study of science demonstrates a level of technological literacy advocated by Grejda and Smith (1994). Students' descriptions of Flamingowatch focused on scientific content and how they used various technologies in learning activities, how they used telecommunications to pursue scientific inquiry, and how the instructional technology was integrated into their science curriculum vis-a-vis Flamingowatch (Grejda and Smith, 1994). The passage above illustrates, in effect, that Ms. Brook's students demonstrate a much higher level of technological literacy that most elementary teachers do (Becker, 1992; Grejda and Smith, 1994).

After each student provided an overview of their views on the Flamingowatch project, I asked them to describe what type of science learning was involved. Jim described the experiments that were done during the fieldtrip. Vern also mentioned the experiments, going into more detail in his description. He described one experiment in which scientists and Kenyan school students tested for the acidity and alkalinity levels in the soda lakes.

Susan's description focused on the ecosystem of the Great Rift Valley, including the habitats of various species. She also described how "hot" the climate was and made connections between climatic factors and the habitats and movements of animals. She pointed out to me that "I think a lot of it was science." Susan further described the antelopes, zebras, gazelles, and elephants' ability to live together in the same geographic area while maintaining separate niches. Susan described in detail the fact that animals' skins were burned by over-exposure to the alkaline water in the soda lakes. Finally, Susan described the fieldtrip's focus on the volcanism of the Great Rift Valley. She pointed out that the volcanic activity in the valley was a topic on the AOL talk shows: "one of the questions on the talk shows was whether the volcano would erupt again." As Susan described the science content of the Flamingowatch project, she was very animated, using hand gestures and squirming in her seat as she talked.

Susan explained her science learning in great detail and also indicated a high level of interest in her Flamingowatch experience. This motivation is indicated by phrases such as:

- I liked it that.........;
- I thought that was pretty cool because........;
- I think it was pretty neat cause.......

These phrases were used to describe what she liked or was enthused about in her science learning. Susan gave a thorough description of the science content beginning with the ecosystem of the Rift Valley, the habitats of various animals, and the hot climate of Africa. Susan also moved beyond <u>description</u> and provided some <u>analysis</u> of the science content by making connections and describing relationships in her science learning. These skills are consistent with the <u>MEGOSE</u> dimensions of scientific literacy (MDE, 1991) and the K-

4 Content Standards described in the NSES (NRC, 1996). Examples of these connections and relationships include these statements or concepts:

- how the animals all lived together;
- influence of soda lakes on animals entering them;
- human population sharing the habitat with animals;
- hunting and population size of animal species.

Finally, Susan also described learning science with technology by describing the study of volcanoes in the talk shows.

Jim spoke briefly about the experiments which were conducted live during the fieldtrip. The experiment he described was a demonstration of the Coriolis effect. Although Ms. Brook's students did not actually do the experiments shown on the fieldtrip video, they did discuss them as a class. Vern continued the discussion of experiments by describing the acidity levels in the soda lakes and how the volcanic process related to that of combining baking soda and vinegar.

For the most part, students described Flamingowatch in terms of both its science content and the role technology played in learning it. Given the fact that students were interviewed about Flamingowatch several weeks after the actual fieldtrips, I feel the passages included in this section indicate a fairly strong retention of the concepts presented in Flamingowatch and a sophisticated understanding of the instructional technology utilized in the project.

In her study on children's knowledge construction in science, Shapiro (1994) used "personal construct theory" to explore how students constructed their own meaning in studying science. The attainment of scientific literacy involves students' ability to construct their own scientific knowledge through scientific inquiry (MDE, 1991). How Ms. Brook's students learned specific science content in Flamingowatch and other similar projects could be the focus of further research.

After talking about the science content in Flamingowatch, I asked students to describe the role technology played in the project. Vern, Susan, Jim, and Jackie talked extensively about their use of technology in the various components which comprised

Flamingowatch. Transcripts of their responses filled many pages in my notebook. Following are some of their responses to my questions.

Vern: If we didn't have technology with Flamingowatch we would Not have been able to do it. We couldn't have seen the people because with the technology we wouldn't have pictures to send back and forth and um, they went inside of the control room and there were all these video cameras...and TVs....and wires and cables....And, Flamingowatch was different because it wasn't in a book it was, was just sort of talking to you and when you heard someone else that you knew taking the questions.......technology I think is a lot more fun way to do it, I like reading and all, but this was a more enjoyable experience than say just reading a book. It was much more alive and you could actually see they were doing this right there, right now, and it was more fun that we got to send in our questions and hear familiar voices and we would enjoy it every day.... we would kinda say when are we going to do the Flamingowatch?? It was exciting.

Susan: Well, we're sending them (messages) to the people in the Rift Valley to ask them questions like about the ecosystem, and habitat, and animals and the water, the lakes and there were lots of things we did not know and they gave a lot of information, I think we learned a lot cause some things we didn't know......I really like using the computer (very enthusiastic) I love to type and everything and I think it's pretty fun doing things like that, Voyager and cause I don't have stuff at home like that and it's just fun to go to school sometimes and use the computer...I think it's really cool.

GC: There's no question that it's fun; in terms of your learning, do you think using the computer has an affect on your learning?

Susan: Yeah I think it does (says firmly, with confidence). It taught me a lot more about different computer programs. I wouldn't know about or Voyager or email, anything like that before I came into Ms. Brook's classroom and so now I know a lot more about computer programs and I've learned a lot more about different kinds of topics that I'm starting....

Susan also described how as a class, students had used similar technology in the electronic fieldtrip to the Okefenokee Swamp as well as utilized the Internet to contact people in Germany and Italy who were working on similar projects.

Vern expressed the importance of instructional technology to scientific inquiry when he said "If we didn't have technology with Flamingowatch we would Not have been able to do it." Vern goes on to describe at least two components of Grejda and Smith's (1994) standards for technological literacy: design and develop student learning activities that integrate computing and technology for a variety of student grouping strategies and for diverse student populations; and demonstrate knowledge of multimedia, hypermedia, and telecommunications activities to support instruction. The Flamingowatch project, given its emphasis on real-time telecommunications, also reflects the type of project Grejda and Smith (1994) advocate in their standards for technological literacy: identify resources for staying current in applications of computing and related technologies in education.

Students spent several weeks researching their animal and in planning for the live, interactive research conference with students in Lincoln school. I asked students to describe how they used technology in researching their animal.

Jackie: I have a computer at home and it has an encyclopedia in it and I look up pictures of baboons and then they give me pages and pages of information about baboons and I pick the pages that give me the most information and then I print those and how then the best pictures, and bring them in and then my group would go over what I found and answer the questions that we needed to answer......

Vern: In the library we use them (CD-ROM's) and.......we take turns and eventually we get to use it and she [librarian] has one on mammals, stuff like that.....

Jackie: They're very easy to use because I learned how and then you can get a report on an animal you look up.......

Vern: It's not like using a book or dictionary, sometimes you just have to type in the name and push return and....you're there! Well, with the rhino report, instead of writing in a tiny book or on paper, I'm writing on the computer and writing about what I've looked up and then I got a page on my animal for the Kenya thing......

I stated previously that students seemed to have a sophisticated understanding of the instructional technology they used in Flamingowatch and other technology projects. In this passage, students were asked to describe the role technology played in the Flamingowatch project. Students described the technology they used, but also discussed how using technology related to their learning in general, and the science content specific to Flamingowatch. The following phrases capture the spirit of the students' responses to my questions:

Vern

•If we did not have technology, we would NOT have been able to do it;
•And Flamingowatch was different because it was not in a book.....;
•Technology I think is a lot more fun way to do it;

•It was much more alive and you could actually see they were doing this right there......;
•We got to send in our questions and hear familiar voices and we would enjoy it every day;
•It was exciting;

Susan

•I think we learned a lot cause some things we didn't know;
•I really like using the computer.....;
•I love to type and everything and I think it's fun doing things like that.....;
•I think it's really cool;
•It taught me a lot more about different computer programs;
•Now I know a lot more about computers.

In chapter 6, Ms. Brook described the motivational nature of instructional technology. The responses above indicate students seemed to be very motivated by using instructional technology in projects such as Flamingowatch. Susan also attributed her ability and opportunity to use computers and other technology to Ms. Brook's efforts at providing the class the opportunity when she stated:

> I wouldn't know about Voyager or email, anything like that before I came into Ms. Brook's classroom.....

While I acknowledged that using technology was fun and motivating for them, I pressed students to describe how using technology affected their learning. Students described how they actually used the technology both at school and at home. They also distinguished the positives of using technology and differentiated it from "book learning." The following phrases relate their thinking on their use of technology in studying science:

•We talked to other people in other places.....;
•We type in questions when we ask the experts things and then they can answer our questions.....;
•After the show, they'd be on-line.....;
•Oh yeah, I have a computer at home and it has an encyclopedia.....;
•In the library we use them (CD-ROM).....;
•They're very easy to use because I learned how.....;
•It's not like using a book or dictionary - sometimes you just have to type in the name and push *return* and you're there!;
•Instead of writing in a tiny book or on paper, I'm writing on the computer.....

These phrases illustrate students' enthusiasm for the technology (push return and you're there!) as well as the process of communicating through the talk shows. In terms of conducting research on their science topics, students appreciated having a world of reference information at their fingertips through the technology they were using. Again, I feel they showed a sophisticated knowledge of how technology affected or contributed to their science learning.

Students' Beliefs About Their General Use of Instructional Technology

One theme that emerged clearly in Ms. Brook's view of science teaching and learning is the importance of accessing and sharing information. Because students were actively engaged with a content and problem centered curriculum, they spent a considerable amount of time using instructional technology to find, organize, and apply information. They also encountered situations in which the information they found and shared with others was conflicting. How did they think about and resolve such issues? What did they think about their use of instructional technology to study science? How did they see the role of instructional technology in doing their research? Through formal interviews, usually in pairs, I asked students to describe their use of technology in the various projects they had completed.

Vern, Jim, Susan, and Jackie described in detail the various ways in which they had utilized instructional technology in the projects they had completed. Vern described using microphones, video cameras, televisions, satellites, and "all sorts of technology." He also described using computers in the Flamingowatch project to type questions into the "talk shows" after each fieldtrip and to generate their research reports.

Vern also described the interactive nature of the technology used in collaboration with Lincoln school and the role of XYZ Cablevision in making the technology available. Vern stated "we have four classes working together so it would be really hard without the XYZ Cablevision connection.....and it really helps to be able to look at different classrooms at different times." Vern's comment reflects the importance of the social aspects of what Fisher et al., (1994) referred to as the new pedagogy: "Interaction among students about the subject matter is valued as an important channel for acquiring, developing and refining knowledge" (p. 124). Finally, Vern described the value of sharing information through live, interactive television when he said students learn more by researching collaboratively. He stated that an advantage of the collaborative research was that "somebody else might have found out something else that you didn't know, and maybe we could put that down in our final report."

Jim also was knowledgeable about the technology itself and revealed an appreciation of the role of technology in doing a collaborative research project. He realized that without the interactivity of the technology, collaborating with students at Lincoln would have been impossible. In commenting on the collaboration in the Flamingowatch research project, Jim stated "It's fun to share information so each time the people get more and more information that they haven't had..." Vern expounded on Jim's analysis by stating:

> They might have different resources .....different books at the other school that you might not have access to ....they might have different computer programs and all sorts of other resources that we might not have so they might have different information and um, so you could also share ideas like um, well, maybe we could do this or do that......or well, that's a good idea.....you could do the work on your own without cooperative groups, but it would be really hard......and um, it's fun doing it with other people, with your friends, and ....and sometimes it's harder to work alone......

Thus, both Jim and Vern emphasized the utility of the collaborative process, in which instructional technology played a key role.

During the Flamingowatch research project, students worked within their own cooperative group, and also shared findings with students at Lincoln school who were researching the same topic. As students shared information in a variety of ways, it became apparent that a certain amount of conflicting information was emerging. In Beichner's (undated) study on students' use of multimedia technology in science learning, he reported the students' central concern was the accuracy of the information they were sharing with others through multimedia presentations. To determine if this was an issue with Ms. Brook's students, I asked students whether they ever found incorrect information on the computer. Jim responded by pointing out that sometimes two people study the same thing but they draw different conclusions, thus contradicting each other. Susan thought about the question for a few seconds and then stated:

> Um.......(thinking), on the computer at my friend's house, one time, that I've seen it said that baboons traveled 200-300 in groups, they only travel 50-100 in groups....I guess that was one thing that they didn't do right and I don't think it's ever given me wrong information on MY computer, but it did a little bit on that computer.

I followed Susan's response by pointing out to her that during the presentation with Lincoln school, I noticed there seemed to be some conflicting information. Susan responded:

> Uh hum, well I thought it was really cool because I used ENCARTA and they used ENCARTA so we both used ENCARTA but we had different information......ENCARTA is the electronic encyclopedia..........

Pushing Susan, Jim, and Vern a bit more, I asked them to explain how they would know when information was contradictory. Jim stated that when researching on-line, there isn't time to compare information with other sources because on-line minutes cost money. So, "you just really have to agree with all the information that you heard most about..." Even though Susan had stated that information from ENCARTA could be interpreted differently, Jim was more willing to accept at face value information received on-line. Susan offered a way to confirm or disconfirm information by stating:

> You can keep looking for the information and ask them "how did you find that? Why do you think you're so sure about what you found? We can ask why didn't you look in any books, why didn't you go to the library? You can double check your stuff by using books and stuff.

Thus, Susan recommends questioning the process of accessing information, and using reference materials to verify information found on-line or on electronic encyclopedias. Jackie gave an example of how one group resolved the issue of conflicting information when she stated:

> Well it didn't really happen in our group but it happened in other people's groups like how long the hippo could stay under water and then they wanted to know the exact answer so what we did was those two groups looked in the books to make sure they were reading it right and they I think asked some people and they found out the right answer that it was I think 5 minutes ....You could look back in the book to make sure you read it

> right or you could um, ask an expert that you know....until you find out the same two answers.

In this passage, Jackie also recommended cross-referencing information in order to verify it. She gave examples of how to use different sources of information and also suggested "ask an expert." Although their methods of evaluation of the validity of information were somewhat superficial, knowing they needed to do so represents a sophisticated understanding of the value of information and technology's fallibility as a tool for accessing it. Kay (1991) argued for students' development of such evaluative skills vis-a-vis information accessed via technology by stating:

> As ever more information becomes available, much of it conflicting, the ability to critically assess the value and validity of many different points of view and to recognize the contexts out of which they arise will become increasingly crucial.

At this point, I wondered whether Jackie agreed with Jim that information found on electronic sources was basically correct (Jim didn't state explicitly it was correct, but said due to time constraints while on-line, one had to go with is as being correct). Because Jackie often referred to the electronic encyclopedia as a source she used, I asked her whether she thought the information on the encyclopedia was always correct. Jackie responded:

> Well, yeah it could have mistakes because I think it's from like '94 and that could be like a year ago and it could've changed by now.....the volcano could've erupted again and it could've changed and then that wouldn't have it on there because it's too old and information might have changed as the years go by.......

In this passage, Jackie admitted that even in electronic medium, the information may become old and outdated, thus one would have to question some of the information or verify its accuracy. Thus, these students demonstrated one of the standards for technological literacy recommended by Grejda and Smith (1994): the ability to evaluate and use computers and other related technologies to support the educational process.

Finally, I asked the students how they felt about studying science using a technological approach. I asked them to think about the science content of Flamingowatch and how they utilized technology in that project. Jim described technology as being "really helpful," but also described some of the pitfalls of technology. He described problems associated with the costs involved, and the limitations of using equipment with inadequate memory. However, he spoke positively of being able to use Netscape to browse museums, libraries, and other locations around the world in order to access information.

Jim and Vern both praised using technology as a research tool saying it was easier than "looking stuff up in books," and recognized the ease of researching global resources from the classroom or from one's own home. They contrasted this research approach to the traditional method of visiting the school's library to sort through stacks of books.

In the passages above, students discussed their use of instructional technology over a wide range of curricular projects including Flamingowatch, Kobe, and Iditarod. I conclude this section by summarizing student interview responses which represent student perspectives on using instructional technology. The phrases illustrate how students thought about the technology itself, the role technology played in their learning, how technology use intersected with science content, and technology-related issues. When students referred to sharing information, they referred to using instructional technology to communicate with others.

Student Responses

- We used microphones, video cameras, televisions, satellites - all sorts of technology and without it we would be stuck.....;
- I mean when we were communicating with our friends in Lincoln, that was electronics and that gave us a lot of information;
- We probably wouldn't even be able to have partners with people in Lincoln without using technology;
- Then we worked as a big group, together...it was fascinating!;
- It was just fun presenting our information to other people (electronically);
- It's fun being on camera and you can see yourself;
- It's good to share information because when you get older you can use the technology....;
- I don't think it's ever given me wrong information on MY computer, but it did a little on that computer;
- We both used *Encarta* but we had different information;
- You can double check your stuff by using books and stuff;
- Yeah, it felt like you were really there! (in Kenya during the fieldtrip);
- Technology is really helpful but sometimes it can really get in your way;
- So if you have on-line or *Netscape* then if one place doesn't have what you need you can just hook up to another place and they'll probably have it.

In the data collection process, I accumulated several hours of interviews with students. The interview questions focused on students' use of instructional technology in completing curricular projects such as Flamingowatch, Kobe, and Iditarod. Combined with data obtained through classroom observations, I was able to get a good idea of how students felt about the technology they used and how they saw it contributing to their science learning.

In the quotes above, students indicated knowledge of how they used technology to facilitate collaboration with colleagues at Lincoln school. They described their group work as "fascinating," and the use of video technology as being "fun."

In the section above, students also discussed how instructional technology allowed them easier and quicker access to information while doing their Flamingowatch research projects. However, they also indicated that information found through electronic resources could also be outdated or contradictory, necessitating confirming information by using other sources such as books in the library. Students unanimously indicated that working collaboratively with peers at Lincoln school would be almost impossible without instructional technology.

Like Ms. Brook, Vern commented that while technology is extremely useful in facilitating learning, it can also "get in your way." Vern explained at length that while instructional technology had many good purposes, and was very motivating, technical problems with its use sometimes created problems in the learning process. This is another example of how sophisticated students' understanding of instructional technology is.

Finally, while students generally praised the role technology played in their learning, none held it as the ultimate arbiter of "correct information." All related that even information from electronic sources such as CD-ROM encyclopedias could be outdated or incorrect. Therefore, verifying information from a variety of sources was sometimes necessary in order to be as accurate as possible. This type of critical thinking about their use of instructional technology correlates to the "habits of mind" dimension of scientific literacy that educators and policy-makers are so strongly advocating.

Ms. Brook's students described their use of various technologies used in the curricular technology episodes and through their explanations of how they used technology, made it clear that they often evaluated the information they were accessing with the technology. In terms of accessing and applying information to scientific inquiry, Ms. Brook's students are learning to make the paradigm shift to the information age. Viau (1994) makes this point below:

> As the flood of information continues to inundate us, our educational objective must change. Information is no longer simply organized, stored, and made available; it has become dynamically changing, random access flood, and it will not help to try to simply *learn about it* - our students must learn to *shape it*, to select and shape information as our forebears shaped and selected wood and clay. To do so requires understanding and judgment as well as knowledge. (p. 6)

In their analysis and description of how they used instructional in general, Ms. Brook's students provided evidence that they not only understood the technology, but also understood it was not without problems, and evaluation and judgment must be exercised in its use.

Viau (1994) also raises another point that helps highlight the contrast in scientific inquiry paradigms described in this section: "As educators we are talking about preparing students for the information age and exploring avenues for doing so" (p. 6). I argue that in the NSES model of scientific literacy, students are prepared in a traditional way of thinking about scientific content and issues. I question whether that model actually prepares students for the information age in which they are currently living. Instead I argue that while Ms. Brook's teaching incorporates much of the NSES model, her pursuit of scientific inquiry through utilization of up-to-date instructional technology comes much closer to actually producing scientifically literate students who are capable of confronting social and scientific issues in the "information age." Given that Ms. Brook is operating in a new paradigm, questions arise about what type of curriculum is appropriate for a technology-rich classroom, what that curriculum looks like, how the classroom should be organized, and what the teacher and students do in such a classroom (Viau, 1994). These questions get right at the heart of the purpose of this study and were addressed by the description, analysis, and interpretation in chapter 6. To further highlight the importance of Ms. Brook's emphasis on utilizing instructional technology to access, share, and apply information, I quote Viau (1994):

> Information has been released from its physical embodiment and set free to flow in streams of energy: Its form, its content, its quantity, its accessibility, its velocity, its organization, all are undergoing violent mutation. We must try to understand this transformation, which is occurring with dazzling rapidity; we must try to isolate those skills and qualities of mind which will empower our children to utilize this flood. (p. 6)

Thus, regarding how teachers and students utilize instructional technology, Viau's ideas are very close to Ms. Brook's, and contrast with the view of technology described in the NSES (NRC, 1996; and Benchmarks (AAAS, 1993). As Viau pointed out, learning about technology will not prepare students, as future citizens, to utilize technology to address social or scientific issues.

In this study, Ms. Brook stated that her teaching emphasized teaching students how to find and use information, and de-emphasized teaching her students to master a static body of knowledge. Viau (1994) supports that approach by arguing that it is fruitless to only attempt to master content or knowledge because the amount of new knowledge is doubling at ever-increasing rates. Thus, knowledge is not static because today's knowledge is "being superseded by changing attitudes, political developments, and recent discoveries" (Viau, 1994). According to this argument, today's students will be best served by learning how to utilize technology to access the information they need. MEGOSE (MDE, 1991), the NSES (NRC, 1996) and AAAS (1990; 1993) would all be in agreement with Viau's conclusion about knowledge and accessing information:

> As memorizers, we cannot compete with computers. The best use of human minds in the future will not be information memorization but transforming raw information into useful knowledge. (p. 6)

Summary of Findings

What types of skills will ordinary citizens need in order to address issues and solve problems in their natural world? The NSES and Benchmarks argue that traditional scientific inquiry will produce scientifically literate citizens capable of functioning as productive citizens. However, I argue that while traditional scientific inquiry has utility, tomorrow's citizens will gain their knowledge through the type of scientific inquiry Ms. Brook is teaching her students - one based on utilizing multiple resources and especially instructional technology to access information in order to apply it to solving problems or addressing social issues. Cuban (1993) would probably find this an optimistic view of the future role of instructional technology in America's schools. However, Papert (1993) and Johnson et al., (1994) argue that instructional technology will play a much stronger role in classrooms in the 21st century. Papert (1993) refers to the changing role of technology in education as a "megachange," arguing that technology will become more influential by forcing epistemological changes in the way we think about teaching and learning. If megachange occurs as Papert suggests, then Americans will develop the technological literacy required to analyze and deal with scientific and technological issues.

Bybee (1993) argues that skills used in scientific inquiry, those described in the NSES, are usually taught in the context of designing experiments, but "they can and should be applied to personal and social problems as well" (p. 83). As the Kobe project indicated, Ms. Brook's views on scientific literacy and inquiry included producing socially conscious students who understood the role of science and technology in their personal lives (Hurd, 1970; 1972; 1984).

Shen (1975) wrote about three related but distinct forms of scientific literacy: practical, civic, and cultural. Shen's view of civic literacy, that one has the responsibility to address social issues, is especially relevant to Ms. Brook's view of scientific inquiry and this view was manifested in the Kobe project. Civic literacy is the awareness of science and technology as they relate to social problems or issues (Bybee, 1993). In terms of the

Kobe project, Ms. Brook's students were concerned about the Kobe earthquake victims. Through their hunanitarian effort, they also learned about the geologic as well as social aspects of the Kobe earthquake.

The following vignette illustrates the type of scientific and technological issue that citizens frequently face in their daily lives:

> Ten miles out of town, at a rural crossroads, stands a handful of houses. Families moved to this small hamlet because of its serenity and quiet, rural setting. Surrounded by crop and pasture land, this small hamlet is far from the noise and pollution of nearby cities.
>
> One day, residents of this hamlet read in the local newspaper of corporate plans to excavate a rock quarry in the corn fields behind their homes. Because other quarries were located in the county, people were familiar with the nature of the industry: blasting, excavation, noise, dust, and an endless stream of huge machinery to move the stone. The company's plan was to excavate to the corporate property line, a mere one hundred feet from the private properties.
>
> Most of the neighbors felt the quarry would forever destroy their quality of life, and would lower property values. Thus, they were against the quarry. A few folks hoped the quarry would bring in a few jobs. They were for the quarry. In the first round of negotiation on the issue, people were allowed to address the county zoning commission.

In addressing an issue such as this, would citizens be likely to design an experiment utilizing the abilities in the NSES Content Standards in order to try to resolve this issue? I think that scenario highly unlikely. Citizens would be more likely to utilize a variety of resources, including instructional technology, to access and accumulate as much information on the issue as possible. This information would be evaluated, and applied to either support or oppose the quarry. This approach to scientific understanding and problem solving is consistent with that argued by Hazen and Trefil (1991). Given that today's students live in the information age (Viau, 1994), the latter model of scientific inquiry would best prepare them to address issues such as the one I describe here. Harlow et al., (1994) argue that this type of inquiry promotes "world literacy." In this view, computer and interactive technologies "empower the student to reach beyond his classroom to areas of concern and interest" (p. 417). This global view of inquiry encourages the student to "work directly upon the world, to learn about it and even affect it" (Harlow et al., 1994, p. 417).

Bybee (1993) argues that students need to develop a global perspective so that as citizens they will be prepared to help solve social problems even on a global scale. A finding of this study is that through implementing a technology-rich curriculum, Ms. Brook is preparing her students to solve problems and address social issues by gaining their knowledge through technology-driven inquiry. In Ms. Brook's model of scientific inquiry, students primarily gain their knowledge through utilizing instructional technology to access information. Clearly, Ms. Brook's students expressed that she was teaching them to pursue scientific inquiry by utilizing instructional technology. Thus, these findings focus on a new paradigm of scientific inquiry, one in which students' real world is expanded to global proportions, information is accessed utilizing instructional technology, and information is shared through collaboration. Jackson et al., (1994) argue that project-based, technology-enhanced science learning makes school science more "real" for students. The "realness" of technology-based science learning was due to the current nature of topics studied and the fact that through telecommunications, similar investigations were being conducted by students' peers outside of their classroom (Jackson et al., 1994).

The importance of accessing up-to-date, valid information and applying that information through collaborative problem solving was expressed by Ms. Brook's students. According to Swan and Mitrani (1993), technology-rich classrooms are more student-centered and cooperative than normal classrooms. Thus, the technology is key in promoting scientific inquiry as Ms. Brook does in her classroom. As Viau (1994) argued, the amount of information available to students continues to explode and the charge of educators is to empower students with the skills to utilize that information.

Where will normal citizens learn to utilize instructional technologies in order to address relevant social issues? I argue that Ms. Brook and teachers like her prepare future citizens by implementing technology-rich curriculum in their classrooms. Although few elementary teachers currently utilize instructional technology to the degree Ms. Brook does (Becker, 1994; Cuban, 1993), technology is here to stay and there is increasing focus on its use in classrooms (Bruder, 1993; Novelli, 1993; Maddux et al., 1994).

Another avenue for the preparation of normal citizens in learning to access information is through the continued improvement in schools' libraries and media centers. Amthor (undated) described elementary and middle school media centers where students worked in groups to do research using state-of-the-art multimedia technologies, including the Internet, to research social issues. These research projects were of a collaborative nature, similar to those implemented by Ms. Brook. More and more, school libraries are open to the public and public libraries offer access to information through instructional technologies. Thus, members of the public currently have access to the types of technology needed to pursue scientific inquiry as per Ms. Brook's paradigm. However, education is critical in this process. As Ms. Brook's students stated, one must be able to evaluate the validity of accessed information in order to apply it in the inquiry process. Kay (1991) described a future in which powerful, intimate computers will become as commonplace as televisions and will be as routinely connected globally as telephones are today. Thus, ordinary citizens will have the capability to address issues such as the quarry issue by researching it on the Internet, or future technologies, and debating the issue with neighbors and government officials. This approach to scientific inquiry is more plausible than the NSES model of pursuing inquiry. Attaining scientific literacy in the 21st century will best be accomplished through implementing technology-rich curricula in K-12 schools and promoting the type of scientific inquiry Ms. Brook advocates.

CHAPTER 8

MS. BROOK: AN EXEMPLARY SCIENCE TEACHER

Introduction

The findings of this study established Ms. Brook as an exemplary technology-using teacher and documented three types of technology episodes in which instructional technology was utilized in pursuit of scientific literacy. In chapter seven, I described Ms. Brook's view of scientific inquiry, a paradigm that is student-centered, technology-driven, and a contrast to traditional views of scientific inquiry such as those in the NSES (NRC, 1996). The study also examined Ms. Brook's knowledge, values, and beliefs about scientific and technological literacy, teaching and learning, instructional technology, and scientific inquiry. In this chapter, I focused on the following research question:

Research question 8:
What makes this teacher an exemplary elementary science teacher?

In framing this chapter, I chose to focus primarily on the National Science Education Standards (NRC, 1996) as they have been an important framework throughout this study. I supplement my analysis and interpretation with other important references reviewed in chapter two. In the following section, I do not attempt to re-state the evidence from chapter four. Rather, I state the NRC Science Teaching Standards, and provide description, analysis, and interpreting in presenting evidence for why I think this study highlights Ms. Brook's exemplary practice. In doing so, I may not address each specific sub-component of each Standard, but will address the overall intent and spirit of each Standard.

Relevant Data, Analysis, and Interpretation

Although this chapter focuses on exemplary science teaching, it is difficult not also to think about what constitutes good teaching in general. Despite decades of educational research, scholars still struggle to describe expertise in teaching (Shulman, 1987). Most studies have focused on teachers' management of students rather than the ideas within classroom discourse (Shulman, 1987). This study described a case of an exemplary teacher, thus representing the type of study Shulman claimed is underrepresented in the educational research literature.

Much research has evolved in the past ten years that focuses on exemplary teaching (Shulman, 1986; 1987; Berliner, 1986; 1988; Sternberg and Horvath, 1995). Developing knowledge of what it means to be an expert or exemplary teacher has become urgent given the nationwide attention to the systemic reform of public education (Sternberg and Horvath, 1995; AAAS, 1990). Berliner (1986) described several reasons for studying expert teachers, arguing that such cases allow us to learn about effective teaching and design teacher education programs based on that knowledge. Shulman (1986) argued that such cases were essential to novices in developing their knowledge of pedagogy. Thus, a rationale for continued research into exemplary teaching practice has been established in the literature.

Several scholars and reform initiatives have described exemplary science teaching and the qualities of exemplary science teachers (Tobin and Fraser, 1987; 1989; AAAS, 1990; Raizen and Michelson, 1994; NRC, 1996). Science for All Americans described effective science teaching this way:

> In planning instruction, effective teachers draw on a growing body of knowledge about the nature of learning and on craft knowledge about teaching that has stood the test of time. Typically, they consider the special characteristics of the material to be learned, the background of their students, and the conditions under which the teaching and learning are to take place (AAAS, 1990, P. 185).

Raizen and Michelson (1994) described several characteristics of effective science teaching and argued that exemplary science teachers possess skills that are rich, complex, and dynamic. Their argument is congruent with Shulman's; that exemplary teachers need knowledge of subject matter, their learners, curriculum, assessment, and understanding of pedagogical content knowledge in order to create teachable lessons.

Tobin and Fraser (1989) synthesized the findings of eleven case studies of exemplary science and mathematics teachers in their Exemplary Practice in Science and Mathematics Education study. This examination of exemplary teachers in primary through high school science and mathematics produced four outcomes:

1) exemplary teachers utilized effective managerial strategies;

2) exemplary teachers adopted practices which encouraged student participation in learning activities;

3) exemplary teachers monitored student understanding of the content to be learned;

4) exemplary teachers maintained a learning environment which was perceived by students as favorable; and

5) exemplary teachers emphasized engagement of all students in learning (Tobin and Fraser, 1989).

Tobin and Fraser (1989) like Shulman, also argued that their study indicated that both content knowledge and pedagogical content knowledge were essential ingredients for outstanding teaching. Tobin and Fraser (1989) concluded their analysis by defining the challenge to science education researchers: to identify how teachers can continue to improve their knowledge of content and teaching so that their practice improves. Nine years after Tobin and Fraser's study, the NSES (NRC, 1996) has developed teaching standards which are intended to promote excellence in K-12 science teaching. In the next section, I utilize the NSES and other literature to frame my description of Ms. Brook as an exemplary science teacher.

Teaching Standard A

> Teachers of science plan an inquiry-based science program for their students. In doing this, teachers: a) develop a framework of yearlong and short-term goals for students; b) select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experiences of students; c) select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners; and d) work together as colleagues within and across disciplines and grade levels.

Raizen and M

combination

environment

Developing

relevant and

with colleag

teaching (N

science teac

Cont

teachers as t

goals and ob

First, Ms. B

grade. In th

developed a

However, th

Because Ms

science curr

Because the

was offered

while earth

Okefenoke

sites. Ms.

and were o

required d

described

in the high

project.

Raizen and Michelson (1994) describe good science teachers as having the "special combination of knowledge, skills, and disposition needed to create a classroom environment that fosters a deep understanding of science concepts and processes" (p. 30). Developing long and short-term goals, effective planning, designing and implementing relevant and meaningful curricula, using a variety of assessment strategies, and working with colleagues to achieve goals, are all necessary components of exemplary science teaching (NRC, 1996). Being skillful in all these areas also speaks to the complexity of science teaching as described in the NSES (NRC, 1996).

Content standards, combined with state, district, and school frameworks, guide teachers as they select the science topics to teach (NRC, 1996). In terms of long-term goals and objectives, Ms. Brook utilized different methods for organizing her school year. First, Ms. Brook was cognizant of the school district's science curriculum for fourth grade. In the beginning of the school year, she analyzed the topics to be taught, developed a preliminary timeline, and established a schedule for teaching those topics. However, the order in which topics would be taught depended on several factors. Because Ms. Brook utilized instructional technology often, she cross-referenced the science curriculum against Turner Active Learning's schedule of electronic fieldtrips. Because the Okefenokee fieldtrip was offered in the first semester, and Flamingowatch was offered second semester, life science was covered in connection with Okefenokee while earth and biological science were covered in connection with Flamingowatch. The Okefenokee unit was extensive and included several days worth of studying local wetland sites. Ms. Brook stated on several occasions that because such units utilized technology, and were organized thematically, teaching them helped her "cover" the majority of the required district science goals and objectives. The advantages of thematic units were described by Roberts and Kellough (1996) and Ms. Brook and her students participated in the highest level of thematic planning by working together to develop the Kobe project.

A we
effectively a
content and
be taught (S
content by a
knowledge,
selecting fr
meet studen
their own st
curriculum.
current eve
that the stu
an opportun
thus nurturi
1996). Du
demonstrat
curriculum
(1986). T
planned to
earthquak
captivated
case study
O
(Berliner
involved
Brook st
impleme

A well-developed planning scheme enables exemplary teachers to teach effectively and efficiently. Effective planning encompasses well-organized knowledge of content and pedagogy, as well as the social and political context in which content will be taught (Sternberg and Horvath, 1995). Exemplary science teachers select science content by adapting extant curricula, and designing new curricula to meet the interests, knowledge, understanding, abilities, and experiences of their students. This means selecting from mandated content and activities, or creating new units and activities that meet students' needs and interests (NRC, 1996). In doing so, teachers take into account their own strengths and interests as well as the resources available to implement the curriculum. Ms. Brook demonstrated this standard of exemplary teaching by integrating current events into the science curriculum. In fact, Ms. Brook stated earlier in this study that the students themselves decided to pursue the Kobe project. Ms. Brook saw this as an opportunity to develop an earthquake unit which would integrate students' interests, thus nurturing a community of interested learners as suggested in Standard A (NRC, 1996). Due to the thematic nature of planning around current events, Ms. Brook also demonstrated knowledge of how to connect the current events to other subjects in the curriculum, thus demonstrating knowledge of curriculum as described by Shulman (1986). The prime example of this strategy was the Kobe project. Ms. Brook had planned to teach the earthquake unit later in the school year. However, when the Kobe earthquake occurred in mid-January, 1995, Ms. Brook and her students were so captivated by the news that they decided to begin the earthquake unit using Kobe as their case study.

One characteristic of exemplary teachers is that they are "opportunistic planners" (Berliner, 1986, p.11). At the time of the Kobe project, Ms. Brook's class was heavily involved with the Flamingowatch project. In deciding to take on the Kobe project, Ms. Brook stated "We have to do earthquakes sooner or later - may as well be now." In implementing the Kobe project, Ms. Brook carefully planned several ways in which earth science co

project. T

forms, anc

Great Rift

Te

(NRC, 19

deep conc

to learn sc

Michelson

design, ad

demonstra

year. Alth

teachers sl

frequently

premature

careful to

and experi

to me that

opportunit

with Flam

> Th
> re
> cu
> pr
> of
> m
> vi
> is
>
> T
> ai
> "
> n
> s

science content could be integrated with the geology component of the Flamingowatch project. Thus, several lessons and discussions took place in which earthquakes, land forms, and earth forming processes were discussed in the context of using Kobe and the Great Rift Valley as examples.

Teachers' lesson and unit plans provide the opportunity for all students to learn (NRC, 1996). As Tobin and Fraser (1989) argued, exemplary science teachers have a deep concern that all students learn with understanding. The focus on all students' ability to learn science is consistent with current science education literature (Raizen and Michelson, 1994; AAAS, 1990; 1993; NRC, 1996; MDE, 1991). Key to being able to design, adapt, and integrate curricula is a teacher's level of flexibility. Ms. Brook demonstrated a high degree of flexibility on numerous occasions throughout the school year. Although this disposition toward flexibility may seem to be an obvious trait teachers should possess, it is a trait that many teachers do not exhibit. Ms. Brook was frequently willing to take on new topics, table topics in progress, or end topics prematurely if she felt it warranted. In selecting and adapting curriculum, Ms. Brook was careful to plan and organize activities that were appropriate to the knowledge, abilities, and experiences of her students (NRC, 1996). On many occasions, Ms. Brook indicated to me that one must "go with the flow," in order to take advantage of curricular opportunities. Following is an example of how Ms. Brook integrated the Kobe project with Flamingowatch, thus demonstrating curricular flexibility:

> The morning began with SB introducing the CNN Newsroom video reports. Each report was two to three minutes in length, and presented current events issues that would be examined as part of the Flamingowatch project. The first video featured beautiful photography in the game parks of the Great Rift Valley, as well as Richard Leakey discussing the three major threats to the parks' ecosystems. SB instructed students just prior to viewing: "You'll need to decide of the three threats, what the real threat is."
>
> The next video featured the prospect of fencing the game parks as an attempt to thwart poaching. After viewing the video, SB said to the class: "You know, Alexis has a question about how much living space animals need...it's the same with people. I think the people of Kobe are having space problems now because people are crowded close together due to the

qua
carr
prol

As

Flamingow

occurred o

demonstrat

demonstrat

pursuing th

promoted '

strategy fo

Ind

lead to pro

and cooper

tasks. Du

work parti

topics, but

(See comp

colleagues

Ex

disciplines

colleague

other sch

instructio

Flamingo

project (

classroo

on-line c

> quake." Students were divided into small groups where they compared the carrying capacity of the East African savannas with the overcrowding problems in Kobe. (Fieldnotes 1-25-95)

As this passage indicates, Ms. Brook was able to integrate Kobe and Flamingowatch into the same discussion. It is notable that the Kobe earthquake had just occurred on January 25, the same day of this classroom discussion. Thus, Ms. Brook had demonstrated curricular flexibility in utilizing up-to-the-hour information and demonstrated a keen sense of how to make connections within the curriculum. In pursuing the Kobe project through utilizing instructional technology, Ms. Brook also promoted "inquiry into authentic questions," which the NSES describes as the central strategy for teaching science (NRC, 1996, p. 31).

Individual and collaborative planning are vital elements of science teaching and lead to professional growth (NRC, 1996). Ms. Brook attended every grade level meeting and cooperated with colleagues in terms of implementing the fourth grade administrative tasks. Due to her extensive use of instructional technology, however, Ms. Brook did not work particularly closely with other teachers at her grade level. She "covered" all the topics, but her timeframe and teaching strategies were not in lockstep with the grade level (See comprehensive discussion of Ms. Brook's planning and collaboration with colleagues in chapter 7).

Exemplary science teachers work together as colleagues within and across disciplines and grade levels (NRC, 1996). Ms. Brook worked closely with her fifth grade colleague and neighbor, Mr. Santo, and also planned collaboratively with colleagues in other schools (see chapter 9). Mr. Santo also planned thematic curricula, and utilized instructional technology frequently. Because Mr. Santo's class also participated in Flamingowatch, he and Ms. Brook worked closely in planning and implementing the project (see chapter 9). Because Mr. Santo also had an Internet connection in his classroom, there were times when Ms. Brook visited Mr. Santo's classroom to make an on-line connection. I noted in my fieldnotes of February 3, 1995 that Ms. Brook was having tr

how she

to her "I'

flexibilit

Brook an

T

elementa

time wor

my notes

> T
> is
> a
> li
> p
> v
> li
> a
> c
> p
> S
> e
>
> T
> F
> a
> c
> r
> s
> S
> i
> n
> r
> p
> "
> t
> p
> i
> S
> V
> f

This pas

professi

having trouble getting on-line in her classroom when Mr. Santo came in her room to see how she was doing. Noticing she was having trouble connecting to AOL, Mr. Santo said to her "I'm on-line if you want to come over and type in questions." This type of flexibility and collaboration was typical of the professional relationship between Ms. Brook and Mr. Santo.

The Flamingowatch project was planned with two teachers at Lincoln school, an elementary school located in an adjacent suburb. Thus, Ms. Brook spent considerable time working with colleagues across grade levels and in different schools. Following are my notes concerning a Flamingowatch planning session:

> Today at lunch time is a planning session in Mr. Santo's room. Ms. Brook is present as are the fourth and fifth grade teachers at Lincoln school who are doing Flamingowatch. They are included in the planning by using the live, interactive TV setup in Mr. Santo's room. SB and Mr. S. have spent part of the morning hooking up the live TV feed and making sure the video equipment is working. This will be a 4-way conference which is live. Because of the cable connection, they can all see each other as well as communicate verbally. SB and Mr. S. frequently enter each other's classrooms to ask questions, get clarification, check on collaborative planning, etc. The rooms are adjacent to each other, and even though Mr. S. is at fifth grade, he and SB collaborate on many projects, especially the environmental stuff. Theirs is a friendly, and professional relationship.
>
> The purpose of this meeting is to work out some details on the Flamingowatch project. They all have their FW curriculum guide open, and have come to the meeting with specific questions. They begin by comparing the science content of the three FW fieldtrip videos to the recommended activities on page 69 of the guide. All agree that students should be able to choose their own topics to research after the fieldtrip. SB asks: "Would it make sense to take all these questions on page 69 and introduce them to students?" A long discussion then followed about how much on page 69 would be "within the students' grasp." Mr. Santo recommended: "Everyone can do it differently with their own kids, but we probably should look at which questions we want to use." SB offers: "Look at page 51 - I wouldn't mind mixing fourth and fifth on that." They then turn back to page 69. SB suggests: "We can modify the questions on page 69 to better fit our curriculum and kids. The big issue is the fragile interdependence" (all agree that is the most important concept to examine). SB tells all that she's bringing in a geologist to talk about the Great Rift Valley. The next teleconference is scheduled for Friday and SB offers to fax her project information to Lincoln school today. (Fieldnotes 1-23-95)

This passage describes the degree to which Ms. Brook went in her planning and professional collaboration with colleagues. The discussion about adapting curriculum so it was '

differe

that foc

1996).

activitie

project,

discussi

knowlec

or diffic

T

teleconf

using he

Lincoln

decision

compone

T
a)
o
st
re
p
of
d

Ms. Broo

thoroughl

technolog

so, Ms. B

and how

it was "within the students' grasp," and Mr. Santo's comment that "everyone can do it differently with their own kids," demonstrates the component in Teaching Standard A that focuses on selecting science content that meets students' interests and abilities (NRC, 1996). This passage also highlights the teachers' discussion about the appropriateness of activities within the Flamingowatch curriculum guide, identifying the "big issue" of the project, and the teachability of certain concepts given the students' abilities. This type of discussion focuses on one aspect of Shulman's (1986) description of pedagogical content knowledge: having an understanding of what makes the learning of specific topics easy or difficult.

The planning session above was not atypical, as I observed at least four teleconference sessions during the Flamingowatch project. I also observed Ms. Brook using her classroom telephone on numerous occasions to contact her colleagues at Lincoln to clarify issues and planning strategies. Thus, many of Ms. Brook's planning decisions were made in collaboration with colleagues, exemplifying the relevant components in Standard A.

Teaching Standard B

> Teachers of science guide and facilitate learning. In doing this, teachers: a) focus and support inquiries while interacting with students; b) orchestrate discourse among students about scientific ideas; c) challenge students to accept and share responsibility for their own learning; d) recognize and respond to student diversity and encourage all students to participate fully in science learning; and e) encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterizes science.

Ms. Brook's ability to focus and support inquiries while interacting with students is thoroughly documented in chapter four. Through the Flamingowatch and other technology episodes, Ms. Brook supported both long and short-term inquiries. In doing so, Ms. Brook continually orchestrated discourse among students about scientific ideas, and how those ideas integrated with other curricular areas (NRC, 1996).

Wh

focuses on

make deci

how to mo

other peda

makes Ms

continuall

lesson if t

lessons, M

mathemat

weight of

students t

their actu

above eig

minutes,

M
o

By inclu

lesson w

average

C

enthusia

and anal

technolo

technolo

Brook's

themsel

frequen

While Standard A focused on the curricular planning teachers do, Standard B focuses on the complexity of implementing those plans. Teachers of science constantly make decisions about the direction of class discussions, when to break into small groups, how to model the use of science equipment, how to engage particular students and many other pedagogical decisions (NRC, 1996). In keeping with Standard B, one thing that makes Ms. Brook an exemplary science teacher is her ability and willingness to continually make decisions during the course of a lesson, and change directions in a lesson if the situation warrants it. For example, during one of the CNN Newsroom video lessons, Ms. Brook had taken the mythology concept in the video and developed a mathematics lesson from it. In the math problem, Ms. Brook stated that the average weight of her fourth grade students was about eighty pounds. When she asked the students to read the problem, several hands were raised. Several students volunteered their actual weights, many being below eighty pounds, with one or two significantly above eighty pounds. This discussion of students' actual weights continued for about ten minutes, and concluded with Ms. Brook stating:

> May I rephrase this problem? We can change this problem. What's your opinion of which average weight we should use? (Fieldnotes 1-25-95)

By including students' opinions and observations in the discussion, the direction of the lesson was changed. In fact, a new mathematics problem emerged; calculating the average weight of the students.

Over time and with experience, exemplary technology-using teachers become enthusiastic about seeing their students utilize a variety of tools for writing, collecting and analyzing data, and solving problems. Through this facilitation of instructional technology use, teachers become more and more confident in their ability to use the technology themselves and facilitate its use across the curriculum (Becker, 1994). Ms. Brook's use of technology provided a high degree of motivation for her students, as they themselves described in chapter four. Through using the technology herself, Ms. Brook frequently modeled the processes of inquiry and problem solving and encouraged students to

pleasures

classroom

and partici

below desc

how to use

10
vic
exc
att
inc
hal
Br
qu
div
gro
an
no
Ma
mo
Ms
wi
en
int
an
Ms
Di
stu
the
an
im

11
ap
hu
ab
H

Tobin an

conduciv

teaching

from on

observin

students to work together, be open to new ideas, and learn about the pitfalls as well as the pleasures of using instructional technology. In doing so, Ms. Brook organized the classroom and managed students so that all students were active in the learning process and participated fully in the lessons (Tobin and Fraser, 1989; NRC, 1996). The vignette below describes a teaching strategy that Ms. Brook used often while teaching her students how to use the technology.

> 10:00 am - Students have just finished watching the first Flamingowatch video. The excitement in the room is palpable. Students are talking excitedly in pairs, and in small groups. Ms. Brook brings the class to attention by handing out a Factoid sheet to each student. These sheets included facts about the Great Rift Valley of East Africa, its wildlife, habitats, culture, climate, etc. After each student received a sheet, Ms. Brook gave instructions for the next lesson, which involved entering questions into the AOL talk forum. Ms. Brook began this lesson by dividing the class in half. While one group was at the computer, the other group was doing seat work on mathematics problems. Ms. Brook announced "If you're going to log onto AOL after school, come up here now." About twelve students eagerly brought their chairs back to the Macintosh computer and arranged themselves so they could see the monitor. Although this is not a good ratio of students to computers (12:1), Ms. Brook facilitated the lesson so that all students were actively engaged with it. In the next fifty minutes, each student took turns at the keyboard, entering a question into the AOL forum. Seated students were very interested in each other's questions, and the discussion about the questions and answers was continuous throughout this on-line computer session. Ms. Brook stated "Go ahead, type in your questions." Student 1 typed: Did Florida flamingos migrate from Kenya? Ms. Brook, and the other students, were busy discussing the question when an answer came up on the monitor: No. Flamingos evolved naturally in Florida, the Bahamas, and Cuba. In turn, each student entered a question and received an almost immediate answer.
>
> 11:00 am - The groups changed places in the room. As the new group approached the computer, I noticed they sat much closer to the monitor, hunching forward so they could see. This group was very enthusiastic about entering their questions and discussing the responses. Vern asked: How were the bones buried, by volcano or over time?

Tobin and Fraser (1989) found that establishing and maintaining an environment that was conducive to learning was dependent on a close link between classroom management, teaching, and learning. Exemplary teachers are able to conduct successful transitions, from one activity to the next, with maximum efficiency (Tobin and Fraser, 1989). After observing those AOL sessions, I was impressed with the management techniques Ms.

Brook usec

class was a

were not at

questions a

comment i

My
goo
ans
bac

The lesson

componen

Brook moc

and encour

Tea
stu
sys
ana
ass
wit
stu
rep
par

Due to the

strategies.

describe h

•student jo
•teacher f
•student r
•student o
•poetry w
•utilizing

Glynn an

discover

Brook used; every student was busy doing something constructive, while only half the class was at the computer station at one time. Ms. Brook actively engaged students who were not at the keyboard by facilitating lively discussions centering on the students' questions and the inter-student discussions that emerged spontaneously. I recorded this comment in my fieldnotes after this AOL session:

> My feeling is that this forum seems very exciting and useful. SB does a good job of relating questions on-line to questions the kids have. The answers to questions generate much discussion as kids relate the answers back to what they saw in the Flamingowatch video. (Fieldnotes 2-1-95)

The lesson described above illustrates Ms. Brook's ability to put into practice the components of exemplary science teaching as stated in Standard B. In doing so, Ms. Brook modeled the process of inquiry, focused students' discourse about scientific ideas, and encouraged students to share ideas in a supportive, and motivating environment.

Teaching Standard C

> Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers: a) use multiple methods and systematically gather data about student understanding and ability; b) analyze assessment data to guide teaching; c) guide students in self-assessment; d) use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice; and e) use student data, observations of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policy makers, and the general public.

Due to the breadth of this study, I did not focus specifically on Ms. Brook's assessment strategies. However, in describing how she utilized instructional technology, I did describe her use of a variety of assessment strategies including:

- student journal writing;
- teacher facilitated discussions in whole group, small group, and individual settings;
- student research projects which included poster construction and model making;
- student oral presentations of their research in collaboration with their research team;
- poetry writing to express scientific ideas;
- utilizing short essay questions on worksheets.

Glynn and Muth (1994) argued that by writing about science topics, students were able to discover new ideas and clarify their thinking, processes which contribute to students' scientific

involved

An

thus allow

Standard

assessmen

finishing t

one specif

and prior

essay desc

wanted to

students' l

Ms

technolog

classmates

groups wh

involved s

> Ch
> We
> of
> too
> pro
> sta
> be
> co

By active

Ms. Broo

reflect on

demonstr

room to

on East

scientific literacy. As this list indicates, much of Ms. Brook's assessment strategy involved writing about scientific ideas, doing research, or discussing ideas in class.

Analysis of student assessment data gives teachers knowledge about each student, thus allowing teachers to meet the needs of each student (NRC, 1996). In the spirit of Standard C, Ms. Brook attempted, as much as possible, to involve students in a variety of assessment activities, and this was evident in one assessment activity in particular. After finishing the Flamingowatch fieldtrip, students began a research project which focused on one specific animal from the Great Rift Valley. In order to determine students' interest and prior knowledge about East African animals, Ms. Brook asked students to write an essay describing what they already knew about their animal of choice and <u>why</u> they wanted to research that particular animal. Thus, Ms. Brook was able to assess her students' level of understanding and their motivations prior to the research project.

Ms. Brook also developed a good idea of students' ability to use the instructional technology in the classroom by asking students to demonstrate different things to their classmates, and frequently put students in charge of instructing their colleagues in small groups while at the computer stations. Following are examples of how Ms. Brook involved students in this type of activity.

> Children, one of your resources for this research project will be computers. We have two here and others in the lab and library. You can get a printout of your animal and others' animals. Jackie replies "I can do that at home too." OK, we're going into the Internet. Jackie replies again "It's a sweet program!" Jackie, why don't you tell the class about it? Jackie starts by stating "There's more in the program than you can imagine!" Then, Jackie began to demonstrate the different menus of Voyager, describing what could be found at each location.

By actively involving students in demonstrating instructional technology to their peers, Ms. Brook provided students the opportunity to develop their abilities and "assess and reflect on their own scientific accomplishments" (NRC, 1996, p. 42). While Jackie demonstrated the Internet to a small group of students, Ms. Brook circulated through the room to the other computer where John was demonstrating the use of a science database on East African animals. Ms. Brook stated "John, can you go through several examples for them a

time if yo

Sc

throughou

study, I ir

sense abo

how to us

about teac

understan

students t

consisten

the teachi

Fi

close rela

activity is

pursued ir

Science C

fair. Beca

students' r

giving Ms

T
p
s
s
s
f
e
r
i

for them and help them print their animals in color? Then, you all can work here at lunch time if you want."

Scenarios like those above occurred quite frequently in Ms. Brook's classroom throughout the course of the year. While I did not emphasize assessment strategies in this study, I infer that because these strategies were used extensively, Ms. Brook gained a sense about students' knowledge of the technical aspects of instructional technology and how to use it as an educational tool. This relates closely to the discussion in Standard C about teachers using assessment strategies that give them indications of students' current understanding, and the nature of what each student is thinking. Ms. Brook's use of students to demonstrate and explain the various uses of instructional technology is also consistent with components of Standard C which views assessment tasks as "built into" the teaching strategy, rather than afterthoughts to instructional planning (NRC, 1996).

Finally, Standard C used the Science Olympiad as an example that "illustrates the close relationship between teaching and assessment" (NRC, 1996). The Olympiad activity is very similar in nature to the type of problem solving and research students pursued in doing science fair projects. Although Ms. Brook's class did not participate in a Science Olympiad, they did culminate the year by participating in a school-wide science fair. Because my data collection was finished, I do not have fieldnotes or observations on students' participation, but it is significant that each class member did a project, thus giving Ms. Brook assessment data to utilize in her teaching and evaluation of students.

Teaching Standard D

> Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers: a) structure the time available so that students are able to engage in extended investigations; b) create a setting for student work that is flexible and supportive of science inquiry; c) ensure a safe working environment; d) make the available science tools, materials, media, and technological resources accessible to students; e) identify and use resources outside the school; and f) engage students in designing the learning environment.

> Teach
> the in
> value
> and d
> stude
> the c
> respo
> colla
> and i
> scien
> valu

I combine S

respects and

Standards A

Beca

nature, Ms.

resources of

they were o

Iditarod uni

conducive t

Examples o

electronic f

teachers m

students to

not contai

chemicals

classroom

hand, this

Brook's c

Brook als

the exten

Teaching Standard E

> Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers: a) display and demand respect for the diverse ideas, skills, and experiences of all students; b) enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community; c) nurture collaboration among students; d) structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse; and e) model and emphasize the skills, attitudes, and values of scientific inquiry.

I combine Standards D and E because they begin to overlap with each other in certain respects and some components of each Standard bear similarities with components in Standards A and B.

Because the electronic fieldtrips and other technology episodes were thematic in nature, Ms. Brook devoted large blocks of time to the process of inquiry. The full resources of the classroom, library, and computer lab were available to students whether they were on-line with AOL and Voyager, writing poetry or short stories based on the Iditarod unit, or doing their animal research projects. Thus, the learning environment was conducive to students' pursuit of extended investigations of science topics (NRC, 1996). Examples of these extended investigations include the Okefenokee and Flamingowatch electronic fieldtrips and related activities. Standard D suggests that exemplary science teachers make available the science tools, materials, media, and technology needed for students to conduct scientific inquiry (NRC, 1996). Although Ms. Brook's classroom did not contain much apparatus needed for scientific experimentation (e.g. glassware, chemicals, microscopes, etc.), Mr. Santo housed such apparatus in his adjacent classroom, and Ms. Brook borrowed what she needed when the need arose. On the other hand, this study thoroughly documents the availability of technology to students in Ms. Brook's classroom, the nearby computer lab, and the computer station in the library. Ms. Brook also highly encouraged students to utilize their computers at home, even going to the extent of calling students at home in the evening to assist them with Internet access.

Th

students d

The descr

willingne

and how t

Kobe issu

effect a h

Effective

1996; By

In

Viau, 199

familiar v

made Ms.

identify a

Standard

Th
m
co

Chapter f

local com

technolog

throughou

B

variety o

classroon

integrate

of fieldt

for class

The NSES (NRC, 1996) describe a community of science learners as one in which students develop a sense of purpose and assume responsibility for their own learning. The description and analysis of the Kobe project in chapter four documented Ms. Brook's willingness and ability to allow students a significant voice in decisions about curriculum and how to pursue scientific inquiry. In essence, Ms. Brook's students identified the Kobe issue as one they wanted to pursue. Thus, her students worked collaboratively to effect a humanitarian relief effort to support the victims of the Kobe earthquake. Effective science teachers facilitate this type of student-centered scientific inquiry (NRC, 1996; Bybee, 1993).

In many respects, the classroom is a limited learning environment (NRC, 1996; Viau, 1994; Davis, 1994). Shulman (1986) described the importance of teachers being familiar with alternate resources and materials available for instruction. One thing that made Ms. Brook such an exemplary science teacher was that she took the initiative to identify and utilize resources outside the school in science and other curricular subjects. Standard D states:

> The classroom is a limited environment. The school science program must extend beyond the walls of the school to the resources of the community.

Chapter four documents in detail Ms. Brook's utilization of resources well-beyond the local community to those of global proportions. How Ms. Brook utilized instructional technology with her students to collaborate with resource persons and colleagues throughout the community and the world is detailed in this study.

Besides utilizing global resources through the Internet, Ms. Brook also utilized a variety of school and community resources that extended science study beyond her classroom walls. Early in the school year, the Okefenokee electronic fieldtrip was integrated with a study of the local community's wetlands. Ms. Brook conducted a series of fieldtrips in the local community which allowed students to collect data and specimens for classroom analysis. Also, the school was fortunate to have a wetland area on school property, w

Thus, Ms.

scientific i

Ms

beyond th

several gu

•myself:
interest w
Kobe regi

•Ms. Mak
class to di

•Roger Jo
basis as th

•parents:
expertise

•XYZ Ca
XYZ Cab
on Kenya
was creat

Thus, in t

resources

T

good scie

1996) to

Ms. Bro

addressi

1) what

2) how

curricu

the nee

property, which Ms. Brook utilized frequently in conjunction with the wetlands unit. Thus, Ms. Brook's students spent considerable time outside the classroom conducting scientific inquiry.

Ms. Brook frequently utilized guest speakers who extended the students' learning beyond the classroom walls. In my five months of data collection, Ms. Brook utilized several guest speakers including:

•myself: In conjunction with the Kobe project, I showed slides of Japan. Of specific interest were those of the Inland Sea region which gave students visual images of the Kobe region;

•Ms. Maki: Ms. Maki worked for the U.S. Geological Survey, and visited Ms. Brook's class to discuss the geology of the Great Rift Valley;

•Roger Jones: An anchor for a local television station, Mr. Jones visited on a regular basis as the station sponsored an Internet project in which Ms. Brook's class participated;

•parents: Ms. Brook frequently invited students' parents to the classroom to share their expertise on a variety of subjects;

•XYZ Cablevision: The culminating activity of Flamingowatch was a fieldtrip to the XYZ Cablevision studio to be the audience for a panel discussion conducted by experts on Kenya. Scenes from this discussion were edited into the Flamingowatch program that was created for public viewing.

Thus, in the spirit of Standard D, Ms. Brook identified and frequently utilized a variety of resources that extended beyond the walls of her classroom.

This chapter began with the framing question "What makes Ms. Brook such a good science teacher?" I have used the Standards of exemplary science teaching (NRC, 1996) to help frame the activities and events that I observed in the classroom that indicate Ms. Brook's qualities as an exemplary science teacher. I conclude this section by addressing two overarching questions:

1) what motivated Ms. Brook to implement a technology-rich curriculum; and

2) how did she learn to do it?

In describing her motivations to learn about and implement technology-rich curricula, Ms. Brook pointed to two things. First, her background as a writer prompted the need to become technologically literate, that is, capable of utilizing word processing, graphics software, and search technologies in order to write more effectively. For the past several years, Ms. Brook has designed and produced a children's calendar for a major educational publishing company. This task required Ms. Brook to evaluate and utilize graphics software for illustration, search technologies for accessing up-to-date information, and desktop publishing software to organize the calendar. As Ms. Brook stated in chapter 5, "As a writer, I need technology in order to be effective at the writing." Ms. Brook also stated in chapter 5 that even though she had a burning desire to develop her technological skills, she needed help to get started. Her husband assisted her in getting started with productivity software.

As her technological expertise developed, Ms. Brook began to see the utility of instructional technology as a classroom management and planning tool. She began using word processing to design her lesson plans, tests, activities, worksheets, etc. She also began using word processing to communicate with parents and the administration. Ultimately, all her written work pertinent to classroom teaching was done on the computer. As Ms. Brook stated in chapter 5 "I've got an awful lot of stuff that I do in the classroom that's on computer disk right now and it's an easy thing for me to find my stuff." Ms. Brook also felt that the superior appearance of computer-generated documents helped students learn better as compared to hand-written documents. In sum, Ms. Brook's initial motivation to utilize instructional technology stemmed from her background as a writer. However, she quickly transferred her technological skills to bring more efficiency to her daily classroom tasks of planning, management, and communication.

Many classroom teachers utilize productivity software to perform their daily management and communication duties. Ms. Brook also utilizes her technological skills to implement a technology-rich curricula, and this is partly why she is an exemplary science teacher (see chapter 5). However, Ms. Brook has indicated that learning how to integrate instructional technology across her curriculum has proven far more difficult than utilizi

study desc

across the

do it. Hov

I b

developm

evidence

highly mo

students.

challenge

make her

more clos

M

instructio

four tech

bring the

colleague

continue

I

technolo

hyperm

doing.

learn fr

curricu

Thus, a

techno

than utilizing technology as a management tool. There are two reasons for this: 1) as this study described, there are many impediments to integrating instructional technology across the curriculum (e.g. equity of access), and 2) there is very little guidance in how to do it. How has Ms. Brook learned to develop and implement technology-rich curricula?

I believe Ms. Brook's personal qualities are primarily responsible for her development as an exemplary technology-using teacher. This study has provided evidence that she is an inveterate learner. She has a strong disposition to learn and is highly motivated to learn how to make her teaching more efficient and motivating for her students. She initially viewed learning about instructional technology as a personal challenge. However, she quickly learned that instructional technology could be used to make her classroom management more efficient, and her curriculum more exciting and more closely connected to her students' personal lives.

Ms. Brook has pushed herself both formally and informally to learn more about instructional technology in order to integrate it into her curriculum. She attends three to four technology conferences per year, as does her colleague Mr. Santo. Together they bring their new knowledge and skills back to Jefferson Elementary and share it with their colleagues and with students through curriculum implementation. Thus, Ms. Brook continues to be formally trained in technology education.

Informally, Ms. Brook teaches herself how to stay up-to-date with current technologies by spending many hours per week utilizing the Internet, experimenting with hypermedia, and working with students in the school's computer lab. She <u>learns by doing</u>. Ms. Brook is a risk-taker, one who is willing to try new teaching strategies and learn from mistakes made. As described in chapter 6, implementing technology-rich curricula is a risky business because the technology itself is sometimes problematic. Thus, as Ms. Brook described, there is a large degree of "trial and error" associated with technology-rich curricula. In Ms. Brook's view, each technology-based unit implemented provided h

future proj

Wh

newly-acq

Ms. Brook

and time-c

instruction

widesprea

technology

as attendi

many occa

her teachi

goal is to

Summary

In

environm

instructio

and imple

making p

group res

work (A

middle c

Simply

explain

coordin

1991) d

student

provided her with a better idea of how to improve her knowledge and techniques for future projects.

Why don't all teachers attend technology conferences and then build on those newly-acquired skills in the school setting? First, many teachers are not risk-takers, as Ms. Brook is. They perceive integrating technology into the curriculum as troublesome and time-consuming. They do not necessarily have the inclination to learn to utilize instructional technology, and even if they did, there are many impediments to its use on a widespread basis (see chapter 5). Because of her leadership role in implementing technology-rich curricula in her building, Ms. Brook is offered many opportunities, such as attending conferences, that other teachers don't have. Ms. Brook discussed with me on many occasions that in her view, instructional technology was an indispensable aspect of her teaching, both as a management tool, and in curriculum implementation. Thus, her goal is to continue to prepare for its use both formally, and informally as described above.

Summary of Findings

In summary, Ms. Brook provided a positive, supportive, and exciting learning environment in which students pursued scientific inquiry. Through her use of instructional technology, fieldtrips, and a wide variety of resources, Ms. Brook planned and implemented integrated curricula and regularly included students in the decision-making process. The technology episodes provided students the opportunity to conduct group research, which emphasized the collaborative nature of scientific and technological work (AAAS, 1990). Ms. Brook was highly flexible, and willing to "change horses in the middle of the stream" if she and her students needed to diverge from the lesson plan. Simply put, Ms. Brook is a challenging, but fun teacher. There is no single answer to explain how she makes science learning so interesting, while at the same time coordinating her teaching closely to the NSES (NRC, 1996) and the MEGOSE (MDE, 1991) dimensions of scientific literacy. Her dynamic personality, excellent rapport with students and colleagues, love of teaching and learning, and considerable pedagogical content kno

of the NSES

content knowledge help her create a learning community that exemplifies the components of the NSES of exemplary science teaching.

Introduct

Sc

science to

curricula,

MEGOSE

also feel s

meaningfu

Science E

effective s

of an exen

with the N

(1986) an

improvem

exemplary

scientific

In

elaborati

A List o

Finding

Finding

CHAPTER 9

FINDINGS AND IMPLICATIONS OF THE STUDY

Introduction

Science education initiatives advocate a paradigm shift from textbook-driven science to activity-based learning in which students are actively engaged with science curricula, "covering" fewer topics but in more depth (MDE, 1991). The authors of MEGOSE, Science for All Americans, and the National Science Education Standards also feel students' science learning must be connected to their real world in order to be meaningful and contribute to scientific literacy in the nation's populace. The National Science Education Standards acknowledge that effective teaching is at the heart of effective science learning in science education (NRC, 1996). This study provided a case of an exemplary elementary science teacher who taught science in a manner consistent with the NSES, and with the MEGOSE dimensions of scientific literacy. As Berliner (1986) and Shulman (1986) argued, studying exemplary teachers contributes to the improvement of preservice teacher education. This case contributes to the literature on exemplary science teaching as relatively few elementary teachers regularly pursue scientific literacy in their teaching, and fewer utilize instructional technology in doing so.

In this chapter, I first list the study's findings, and then give a chapter-by-chapter elaboration of the findings. I then discuss the implications of the study.

A List of Findings

Finding 1: Ms. Brook viewed scientific and technological literacy as parts of a more general literacy.

Finding 2: Instructional technology was used primarily to access and share information through collaborative problem-solving activities. Ms. Brook's view of scientific inquiry was based on implementing a technology-rich curriculum to develop students' global perspective.

Finding 3: Ms. Brook viewed effective science teaching as actively engaging students in an activity-based science program. Her curriculum was interdisciplinary with a strong focus on science content as well as inquiry.

Finding 4: Ms. Brook viewed learning as most effective when related to students' real world, and when focused on inquiry rather than learning facts in isolation.

Finding 5: Ms. Brook is a risk-taker and inveterate learner. Her preparation to integrate instructional technology into her science curriculum resulted from her attendance at technology workshops, and her learn-by-doing approach to technology use. Ms. Brook learned to integrate instructional technology into her curriculum by spending many hours per week on-line in order to learn more about on-line projects.

Finding 6: Ms. Brook taught science on a regular basis and demonstrated a high degree of both content knowledge and pedagogical content knowledge. Her teaching strategies and views on learning were consistent with the NRC (1996) Teaching Standards.

Finding 7: The technology-rich instructional units implemented by Ms. Brook focused on science content and scientific inquiry. Students utilized the Internet and other instructional technologies to "extend beyond the walls of the classroom" to a global audience.

Finding 8: Ms. Brook's teaching strategies most often involved her facilitation of activity-based student projects. These projects focused heavily on students' use of instructional technology in scientific inquiry.

Finding 9: Ms. Brook utilized existing technology-rich curricula such as Flamingowatch, and Internet projects such as Kobe and Iditarod to supplement her thematic, interdisciplinary science curriculum.

Chapter 4 Findings: Teacher Knowledge, Values, and Beliefs About Scientific and Technological Literacy

Ms. Brook described scientific and technological literacy as being parts of literacy in a general sense. If students could not read, write, think, and communicate, scientific and technological literacy would not be achieved. However, throughout the study, Ms. Brook identified and described different components of scientific and technological literacy.

In each of the technology episodes described in this study, students' ability to access and share information was a critical feature of the inquiry process. Instructional technology was primarily used to access information which was then applied to the problems

informati

problems

the heart

students

M

achievem

being ge

understa

methodo

N

correct s

describe,

Howeve

felt it im

in ways

discours

pursuin

and reso

to use i

my firs

of stud

knowl

topic t

order

Brook

problems or issues being studied. Ms. Brook worked hard to facilitate the sharing of information by giving students the opportunity to work collaboratively on social issues or problems identified in the curriculum. This process of working on "real" issues was at the heart of Ms. Brook's view of scientific and technological literacy. She stated that if students could not pursue this type of inquiry, they would be "technologically illiterate."

Ms. Brook felt strongly that a textbook-driven classroom would not facilitate the achievement of scientific literacy. She viewed the information in science textbooks as being generally outdated, and not related to students' real world. In order for students to understand their real world, teaching must progress beyond the fact-based, didactic methodology commonly associated with the use of science textbooks.

Ms. Brook felt it critical that students engage in scientific discourse, and use correct scientific language in doing so. Scientifically literate students should be able to describe, explain, predict, and ask questions while participating in scientific discourse. However, this type of scientific inquiry is not present in many classrooms, and Ms. Brook felt it important for her to model for her students how to participate in scientific discourse in ways that are acceptable in the scientific community. Active engagement in scientific discourse went hand-in-hand with students' active engagement with the curriculum in pursuing scientific literacy. This activity involved students in using a variety of materials and resources, and especially the instructional technology available.

Although Ms. Brook had extensive experience with MEGOSE, she did not appear to use it or any other reform documents to guide her teaching for scientific literacy. In my first conversation with Ms. Brook about scientific literacy, she related the importance of students being able to know about and analyze current events in order to become more knowledgeable about science. For example, she described flooding in California as a topic that students should be informed about, and have scientific knowledge about, in order to be thoughtful and productive members of the world they live in. Thus, Ms. Brook's teaching seemed to be influenced by her own construct of scientific literacy, not

by any ove
in agreeme
planning fr

Ev
thinking a
teaching c
should be
administra
literacy.
instructio
seem to b
<u>Science I</u>
thinking
If exemp
science t
exempla

T
teaching
emphasi
should i
view go
knowled
the impo
instructi
represer
is impor

by any overt use of MEGOSE or other science education documents. She stated she was in agreement with the principles in MEGOSE, but she did not use MEGOSE as a planning framework in order to effect scientific literacy through her teaching.

Even though Ms. Brook did not utilize MEGOSE for curricular planning or thinking about scientific literacy, the evidence in this case study indicates that her teaching correlated with many of the MEGOSE dimensions of scientific literacy. This should be good news and bad news for science education policy-makers and school administrators. On one hand, here is an exemplary teacher who is teaching for scientific literacy. She is an outlier in her profession due to her frequent and skillful integration of instructional technology in pursuing scientific literacy. On the other hand, she does not seem to be consciously utilizing what she has learned from MEGOSE, Benchmarks for Science Literacy, or the NSES. These documents were designed to help frame teachers' thinking about scientific literacy, and prepare them to be more effective science teachers. If exemplary teachers such as Ms. Brook are not using these various guidelines for better science teaching, then the questions are "Why not?" and "How does she manage to be an exemplary science teacher without using them?"

Throughout our discussions about scientific literacy and effective science teaching, Ms. Brook returned repeatedly to three themes: that textbooks should be de-emphasized, that students should be actively engaged in learning, and that science content should integrate instructional technology. The literature suggests that many teachers view good science teaching as "covering the content," and "transmitting" scientific knowledge to students. Ms. Brook views good science teaching differently, emphasizing the importance of an activity-based science program, the science content itself, utilizing instructional technology, and making science relevant to students' real lives. These ideas represent nothing new, and in fact are ideas suggested in MEGOSE and the NSES. What is important is that Ms. Brook not only holds a view of science teaching that is consistent with the literature and these science policy documents, but also that she implements the science in ways that promote scientific literacy.

Ms. Brook's practice of actively engaging students went beyond providing hands-on experience. She felt strongly that students should interact with one another, working together and sharing information. The use of instructional technology provided a strong conduit to achieving those objectives. In order to teach in this fashion, Ms. Brook emphatically denounced depending on science textbooks. In place of textbooks, Ms. Brook relied on current events, accessing information from the Internet, student research projects, and a variety of resources to promote critical thinking and student collaboration on scientific problems or ideas.

Chapter 5 Findings:
Teacher Knowledge, Values, and Beliefs About
Teaching and Learning

Ms. Brook's knowledge, values, and beliefs about teaching and learning were primarily revealed in her descriptions of science curriculum and how she implemented it. Ms. Brook frequently described her own teaching metaphorically by describing her role as "orchestrating" the teaching and learning, guiding students, providing a supportive environment for inquiry, and facilitating the classroom activities. Much of this orchestration involved teaching students how to access and share information, which was described in this chapter.

Ms. Brook described good science teaching as being activity-based, with a strong focus on science content and the integration of instructional technology. In her view, science curriculum should be interdisciplinary, integrating several subjects, with instructional technology as the common thread linking them. Ms. Brook's view of science curriculum included foci on scientific inquiry, relevant social issues, and students becoming responsible citizens through studying science.

M

students'

her stude

N

linked to

a "conne

curricul

concept

involve

inquiry.

Ms. Bro

informa

inquiry

inquiry

and dis

scienc

qualit

invete

degre

and he

that w

curric

learn

Ms. Brook believed science curriculum was unlimited in scope due to her students' access to the Internet. Searching the world's resources electronically allowed her students to develop a global perspective on scientific issues (see chapter 7).

Ms. Brook believed students learned most effectively when the curriculum was linked to their real world. She argued that the real-world connection to learning provided a "connectedness" in the learning process that was absent in a textbook-driven curriculum.

According to Ms. Brook, activity-based science was essential in promoting conceptual understanding. Thus, Ms. Brook's teaching strategies were designed to involve students in a variety of collaborative projects in which they pursued scientific inquiry. Many of the MEGOSE dimensions of scientific literacy were incorporated into Ms. Brook's technology-rich, project-oriented curriculum.

Ms. Brook associated students' learning with their accessing and sharing information in order to answer questions pertinent to their scientific inquiry. She viewed inquiry rather than learning facts in isolation as critical to her students' learning. In the inquiry process, learning was facilitated through students researching scientific concepts, and discussing those concepts using precise scientific language.

Like many elementary teachers, Ms. Brook's professional preparation to teach science was weak. However, this study provides evidence that teachers' personal qualities are key in becoming better science teachers. Because she is a risk taker and an inveterate learner, Ms. Brook has developed into an exemplary science teacher. Her high degree of technological literacy results from her strong disposition to learn new skills, and her view that learning is a lifelong process.

Ms. Brook believed instructional technology was only a pedagogical tool, but one that was critical to her paradigm of scientific inquiry and central to her science curriculum. She believed that students' use of instructional technology enabled them to learn more effectively because it gave them the ability to access an unlimited amount of scientific

represent

collabora

instructio

througho

M

literate i

emphasi

in "real-

instructi

they we

technolo

technolo

curricul

with a v

episode

The Fl

a three-

nature.

project

a forum

"expert

interdis

scientific information, most of which was much more current than information represented in textbooks. She also viewed technology as the primary conduit to students' collaborating on important issues. Students' real world was expanded through their use of instructional technology and they were able to communicate and collaborate with peers throughout the world via the Internet and other technologies.

Ms. Brook believed that students would not be scientifically or technologically literate if they were unable to utilize instructional technology in the inquiry process. She emphasized that one of technology's primary benefits was that it enabled students to learn in "real-time." Ms. Brook never claimed that students could learn only through utilizing instructional technology, but she argued that their learning was more effective and that they were better prepared to deal with real social issues because of their high level of technological literacy.

Chapter 6 Findings: Teacher Knowledge, Values, and Beliefs About Instructional Technology

The findings in this section demonstrate the potential of integrating instructional technology into the science curriculum. Ms. Brook implemented a technology-rich curriculum that allowed her students to "ignore the walls of the classroom" and interact with a worldwide audience. This study described and contrasted three technology episodes. Below, I briefly summarize my findings about each episode.

The Flamingowatch Project

This technology-rich curriculum reached a worldwide student audience, provided a three-day real-time field trip to East Africa's Great Rift Valley, and was interactive in nature. Students were able to communicate with experts in Kenya in real-time. This project facilitated communication on scientific issues by providing participating students a forum on AOL. Following each fieldtrip, students used AOL to communicate with "experts" on the forum as well as with other students. The curriculum was thematic and interdisciplinary, and emphasized problem solving and inquiry. The Flamingowatch curriculum was informed by the Benchmarks for Science Literacy (AAAS, 1993), and thus the activities within the curriculum were designed to promote scientific literacy. My findings also demonstrated a close correlation of Flamingowatch's activities to the MEGOSE dimensions of scientific literacy.

Ms. Brook believed that curriculum such as Flamingowatch was relevant to students' real world, a finding which I describe more fully in the next section. This view was supported by Davis (1994) and Itzkan (1994) who argued that instructional technologies allowed students to extend their real world to a global audience, effectively becoming global citizens. This study provided a rich description in chapter four of what curriculum and classroom interactions looked like while effecting technology-rich curricula.

Utilization of instructional technology was vital in implementing Flamingowatch. The real-time interactive television broadcast of the fieldtrips were supplemented by students' use of CNN video clips, AOL discussion forums, electronic curricular resources, and the Internet to conduct research on Flamingowatch topics. Ms. Brook characterized Flamingowatch as "unique" due to its richness of technology.

The Kobe Project

In this project, students utilized the Internet to focus on a social issue (helping earthquake victims) and study a science topic (earthquakes). Unlike Flamingowatch, the Kobe project was unplanned and occurred in response to Ms. Brook's students' focus on world current events. This project was developed and largely implemented by Ms. Brook's students, and like Flamingowatch, was global in context.

Because the Kobe project focused on a current event, Ms. Brook needed to "table" some curricular projects and activities in order to work Kobe into the daily schedule. This level of curricular flexibility is a prerequisite for technology projects of this type. Because Kobe was also interdisciplinary, learning of other subjects and skills were integrated into the Kobe project, thus helping to ease the pressure on Ms. Brook to "cover the curriculum."

The Iditarod Project

This project also utilized the Internet, but was used primarily as a curricular supplement rather than a major science unit. Iditarod was short-lived due to technological difficulties. Thus, Iditarod demonstrated the gamble teachers take in utilizing instructional technology: it doesn't always work as planned. Because of the possibility of technological difficulty when implementing an Internet project, teachers need to be flexible in planning and utilize a variety of resources in teaching the unit. On the other hand, Internet projects such as Iditarod provide a technology-rich supplement to the regular curriculum.

Chapter 7 Findings: Teacher Knowledge, Values, and Beliefs About Scientific Inquiry

The major finding in this section was the contrast between the traditional view of scientific inquiry as represented in the NSES and Benchmarks, with Ms. Brook's view of scientific inquiry, which is based on implementing a technology-rich curriculum to develop students' global perspective. Ms. Brook's science teaching was not exclusive of the NSES view of scientific inquiry, but through utilizing instructional technology to address problems and issues, it did extend beyond the NSES inquiry paradigm.

As Papert (1993) and Johnson et al., (1994) argued, instructional technology will play a much stronger role in classrooms in the 21st century. Increasing use of instructional technology will not only prepare students to address important issues, but will force epistemological changes in the way educators think about teaching and learning. The findings in this section suggest that Ms. Brook views the utilization of instructional technology as a central component of scientific inquiry.

The analysis and interpretation in chapters five and six described Ms. Brook's implementation of a technology-rich science curriculum. Ms. Brook's integration of instructional technology across the curriculum was consistent with Papert's view that instructional technology will play a stronger role in 21st century classrooms. In many ways, Ms. Brook's views on teaching and learning and her utilization of a variety of instructional technologies provides a model for Papert's claims. For example, it is likely that many 21st century classrooms will resemble Ms. Brook's in that curriculum issues will be pursued primarily through students' use of instructional technology. In pursuing scientific inquiry, students in 21st century classrooms will collaborate with peers throughout the world through a variety of instructional technologies.

Ms. Brook's scientific inquiry paradigm focuses on science content but also on social issues relevant to the curriculum and students' interests. She was very aware of the need to teach students to be socially conscious, be aware of their civic responsibility, and develop a global perspective vis-a-vis their real world. Using instructional technology to access and share information was central to this scientific inquiry paradigm. Harlow et al., (1994) argued that this type of inquiry promotes "world literacy" and that this global view of inquiry enables students to "work directly upon the world, to learn about it, and even affect it" (p. 417). Bybee (1993) also argued that students needed to develop a global perspective in order to be capable of addressing social issues, even on a global scale. Ms. Brook's class utilized instructional technology to address scientific and social issues on a continuum from local (wetlands) to global (Kobe).

Current reform initiatives such as the NSES are based on a traditional paradigm of scientific inquiry. In this paradigm, students are taught to solve problems or answer questions by designing and conducting an experiment to test an hypothesis. I argue that Ms. Brook's scientific inquiry paradigm is more realistic in this technological age of information. In the 21st century, it will become even more important for citizens to be able to access up-to-date information and apply that information to address social issues. As Viau (1994) argued, the charge of educators is to empower students with the skills to utilize the ever-exploding amount of information available to them.

Chapter 8 Findings:
Ms. Brook as an Exemplary Science Teacher

In observing Ms. Brook's science teaching over a five month period, I found she demonstrated many of the skills and characteristics of exemplary science teaching as described in the education research literature (NRC, 1996; Raizen and Michelson, 1994; Tobin and Fraser, 1989; Shulman, 1986; 1987; Becker, 1994; Bybee, 1993; Sternberg and Horvath, 1995). In chapter five, I used the teaching standards in the NSES and other literature to frame my description of Ms. Brook as an exemplary teacher.

My findings indicate that Ms. Brook taught science on a regular basis and demonstrated both content knowledge and pedagogical content knowledge in pursuing scientific inquiry with her students. Shulman (1986) argued both of the above were essential ingredients for outstanding teaching. Ms. Brook taught science in such a way that she met most of the NSES teaching standards. She implemented an activity-based science program that was technology-rich. The content and activities were adapted and designed to meet the interests, knowledge, understanding, abilities, and experiences of her students (NRC, 1996).

In planning and implementing curriculum, Ms. Brook collaborated with colleagues in Jefferson school and in other schools. The interdisciplinary nature of the Flamingowatch and Kobe projects enabled Ms. Brook to meet the district's curricular requirements and teach for scientific literacy as recommended by MEGOSE. Berliner (1986) described exemplary teachers as being "opportunistic planners." Ms. Brook demonstrated this quality by effectively facilitating the Kobe project. When her students proposed the Kobe project, Ms. Brook demonstrated a high degree of flexibility by delaying already-planned units, and re-planning units to incorporate Kobe activities.

The evidence in this study showed that Ms. Brook took special care to create activities that were challenging, but within the grasp of her students. In the spirit of Teaching Standard D, Ms. Brook created a learning environment in which students were encouraged to contribute to curricular decisions, and participate in scientific inquiry. In doing so

inquiry a

1993). T

students

Brook u

inquiry.

accessi

discuss

linked

variety

techno

fieldtri

Implic

the im

(AAA

to be b

develo

respon

teache

necess

techno

necess

reform

doing so, Ms. Brook facilitated students' learning and modeled the skills of scientific inquiry as well as the habits of mind that characterize scientific thinking (AAAS, 1990; 1993). The Kobe project epitomized Ms. Brook's willingness and ability to challenge students to take responsibility for their own learning.

Although this study did not focus on assessment strategies, it did find that Ms. Brook utilized assessment strategies that informed her teaching and promoted scientific inquiry. Ms. Brook's implementation of the technology-rich curriculum emphasized accessing and sharing information. Her assessment strategies emphasized writing, discussion, and oral presentations. Thus, teaching and assessment strategies were closely linked and informed one another.

In extending students' learning beyond the classroom walls, Ms. Brook utilized a variety of resources outside the school. As has been extensively described, instructional technology was used to access global resources. However, Ms. Brook also utilized local fieldtrips and guest speakers in implementing her curriculum.

Implications of the Study

Science for All Americans argues that a clear national consensus now exists for the improvement of science, mathematics, and technology education for all K-12 students (AAAS, 1990). In order to effect the systemic reform of science education, teachers need to be better prepared, both at the undergraduate level, and in their continuing professional development (AAAS, 1990; NRC, 1996). However, teachers alone cannot be held responsible for such massive reform, and reform initiatives cannot be imposed on teachers; teachers themselves must play a strong role in shaping reform and receive the necessary support to achieve significant reform (AAAS, 1990).

Current reform initiatives call for closer integration of science, mathematics, and technology, yet this study indicates that most elementary teachers lack the knowledge necessary to achieve such integration in their teaching. How should science education reformers address this situation? I believe that reform initiatives that focus only on K-12 schooling

for All A

in underg

educatio

and peda

in a refo

at the ur

discussi

So wher

T

develop

work or

element

deficien

For mar

and ass

pedago

instruct

that her

utilizin

Given

instruc

teacher

thorou

making

content

schooling will ultimately fail to achieve significant reform. My interpretation of Science for All Americans is that it focuses solely on K-12 schools, ignoring the need for reform in undergraduate teacher preparation. The NSES argues that college and university education faculties need to plan courses that support the integration of science content and pedagogy as described in the Standards (NRC, 1996). However, a policy statement in a reform document aimed at K-12 educators will not succeed in gaining much attention at the university level. Furthermore, the policies in the NSES are essentially void of discussion regarding teachers' integration of instructional technology in the classroom. So where does that leave us?

The National Science Education Standards state that a teacher's professional development is a career-long endeavor. In other words, novice teachers will continue to work on their professional preparation throughout their careers. In working with elementary student teachers for the past four years, I have found them to be seriously deficient in their preparation to use instructional technology in their professional work. For many, using instructional technology for anything beyond word processing papers and assignments seems untenable. In many teacher preparation programs, the pedagogical training needed to increase awareness and effectiveness in integrating instructional technology into content areas is nearly absent. Ms. Brook acknowledged that her own undergraduate preparation did not prepare her for either teaching science or utilizing technology. She has basically learned how to do both largely on her own. Given the complexity of teaching science, and the added complexity of integrating instructional technology into science teaching, science educators cannot expect classroom teachers on a large scale to prepare themselves professionally as Ms. Brook has done.

I think this study's literature review demonstrates the need for a much more thorough preparation of undergraduate students in using instructional technology and in making the pedagogical connection between the technology and how to integrate it into content areas, including science. Technology now makes it possible for K-12 students to learn science in real-time and collaborate with peers throughout the United States and the world. Sadly, only a small minority of elementary teachers are equipped to pursue scientific literacy by involving students with technology-rich curricula, in no small part because they have not been professionally prepared to do so.

Teacher preparation is only a part of the need for systemic reform of science education in K-12 schools. However, I believe a strong implication of this study is that teacher preparation programs need to begin preparing novice teachers in a meaningful way to use the multimedia technology they will be exposed to in K-12 schools. A single program requirement-fulfilling course such as "Technology 101 for Teachers" will not be effective. Such courses already exist in many teacher preparation programs and do little to infuse novice teachers with the confidence and capability to integrate technology in their science teaching. I believe elementary teachers should be required to take courses that integrate mathematics, science, and technology and are sequenced to gradually boost the confidence and skill of novice teachers in utilizing instructional technology. Such courses would involve elementary education majors using the Internet and other multimedia technology the way Ms. Brook and other exemplary teachers do. The Internet provides a rich forum for practicing teachers to share their knowledge of teaching, learning, and curriculum. Novice teachers should graduate from their professional preparation programs with the confidence and ability to join that community of "technologically literate" professionals.

While each college and university will need to structure programs to suit their particular purposes, models of effective technology education programs currently exist (Dell and Disdier, 1994; Freeouf and Flank, 1994; White, 1994; Bao, 1994; Kortecamp and Croninger, 1994; Pan, 1994). While these programs describe a wide array of approaches to preparing preservice educators to integrate instructional technology into their curriculum, I agree with Kortecamp and Croninger on three major aspects of effective technology training:

1) use of instructional technology in preservice teacher preparation programs should include: modeling and engaging students in technology assisted instruction in all their coursework;

2) placing teaching interns in classrooms where technology is a vital part of every school day; and

3) form a partnership with a local school system so that teaching interns can work with teachers and students in the field in realistic projects which integrate instructional technology (Kortecamp and Croninger, 1994).

Based on the findings of this study, I would add one recommendation to the list above. Given the potential of Internet use in science teaching, I recommend that preservice educators have access to current educational listserves such as KidProj and KidSphere. A percentage of science education coursework should be designed to actively engage preservice educators with the real world projects found on these listserves.

Whatever the model chosen, teacher preparation programs should prepare novice teachers to utilize instructional technologies that are consistent with those in the schools in which they will work. Teaching preservice educators to use instructional technologies that are different from or not available in today's schools is impractical and a disservice. Finally, use of instructional technologies in teaching and learning must be modeled by professors of teacher education on a regular basis. As in K-12 education, to be effective, instructional technology must not be an "add-on," but rather it must fundamentally change the way educators think about teaching and learning.

Implications for the Elementary Science Curriculum

If teachers are to get away from textbook-driven science, what type of curriculum and materials will they use? This study presented a case of what teaching and learning look like in a technology-rich classroom. As more elementary teachers become technologically literate, they will need more models of technology-rich curricula to adapt to their science teaching. Curriculum units such as Flamingowatch are becoming more established as curriculum supplements, and should provide effective models for how to teach science using thematic, interdisciplinary, technology-rich curricula.

If, as Ms. Brook suggested in this study, science curriculum consists of anything that can be accessed on the Internet and the World Wide Web, and if students' real world can be anywhere they can travel electronically, then what are the implications for the elementary science curriculum? Clearly, the scope of science curricula will be greatly expanded by those teachers who integrate instructional technology into their curriculum. Utilizing such current, electronic media to supplement or drive science curriculum will increase the level of collaboration and inquiry among students, and decrease the level of textbook-driven science.

Finally, Ms. Brook's scientific inquiry paradigm provided a stark contrast to the traditional paradigm as described in the NSES. I argued that her technology-driven paradigm that focused on investigating social and scientific issues by accessing and applying information would be more effective in preparing students for the level of scientific and technological literacy required to deal with today's complex societal issues. If that is the case, then what should the elementary science curriculum look like? How should it differ from what it is now? Clearly, how teachers integrate instructional technology into their curriculum will affect the direction elementary science curriculum takes in the future.

This study examined a very complex relationship, how the use of instructional technology is related to students' attainment of scientific literacy. I agree with Ms. Brook that utilizing instructional technology is only one way to help students become scientifically literate. However, by its very nature, technology allows students and teachers to explore science curriculum in a much more collaborative, current, and interesting way. Rhetoric from the public and from reform initiatives indicate an escalating emphasis on integrating technology into all curricular areas. Instructional technology is a natural fit with science curriculum. Thus, what is the implication for science curriculum? The Benchmarks for Science Literacy advocate that to become more scientifically literate, students need to learn much more about technology (see chapter 2). An implication of this study is that students also need to learn much more about how to use instructional technology to achieve what the policy documents describe as authentic, real-world learning. This study should contribute to the literature on what it looks like in the classroom when teachers implement science curricula in a technology-rich environment.

Implications for Further Research

There are three areas in this study in which I think further research is necessary. First, one of the foci of the NSES is assessment. This study did not focus on Ms. Brook's assessment strategies as that would have broadened the scope of the study. Assessment is worthy of a major research effort, especially in technology-rich classrooms such as Ms. Brook's. For example, Ms. Brook felt students' use of instructional technology promoted "real-time" learning. How does one assess the effectiveness of this type of learning? The Standards (NRC, 1996) state that "the feature that is to be measured is actually measured" (p. 83). Thus, did Ms. Brook actually have an assessment strategy to measure the effectiveness of what she termed real-time learning?

Next, the whole issue of Internet use in science classrooms requires further research. This study reviewed literature that described the motivational aspects of Internet use as well as the benefits to learning. Does Internet use really expand students' real world? Does it actually lead to students developing global perspectives and becoming global citizens? And will electronic access to information actually supplant traditional approaches to scientific inquiry as this study claims? I do believe that use of instructional technology is here to stay, in our schools, and in our society. Therefore, we need to learn much more about how students and teachers are utilizing instructional technology to solve problems and address social issues.

Finally, I agree with the literature that expresses concern about the proliferation of technology-based learning before adequate research and evaluation has been undertaken to examine its effectiveness (Waxman and Padron, 1994). For example, two well-known programs, Apple Classrooms of Tomorrow (see Dwyer et al., 1990) and IBM's Writing to Read have come under question by educators and researchers (Waxman and Padron, 1994). There has been relatively little research done in the field of technology and teacher education. Although this study only touches on that issue, it indicates more research needs to be done in this area.

Significance of This Study

This study makes a significant contribution to the case literature on exemplary elementary science teachers. Tobin and Fraser (1987), Shulman (1986), Berliner (1986), and Penick and Yager (1983) all advocated the need for this type of research in science education. Because of this study's focus on an exemplary technology - using elementary teacher, it helps fill an even greater void in the research base.

This study examined various aspects of science teaching and learning in a fourth grade classroom. While current reform documents advocate a stronger relationship between science, mathematics, and technology in the pursuit of producing scientifically literate students, this study indicates that the synergy needed to effect that reform is not yet fully in place. In Ms. Brook's classroom, instructional technology was often used to assist students in their construction of new scientific knowledge. How did they do it? What type of curriculum successfully combines science learning with instructional technology? This study adds to our understanding of science teaching and learning through its detailed description of an exemplary teacher and her students, and the ways they used instructional technology to help make sense of their world.

CNN VIDEO REPORTS: FLAMINGO WATCH

1-24-95 Vern

CNN VIDEO REPORT	CAUSE *(The reason something has happened...)*	EFFECT *(What happened as a result of the cause...)*
ZEBRA MUSSEL INVASION	it got into the lakes because ships filled there bilges with babies then let them out in lakes	They clean the water out so well that fish can't breathe and die.
EXOTIC WATER WEEDS	Eouropeans brought some from south america then they got loose.	They make a thick carpet on the water so the underwater plants don't get sun

Use these words to write a summary of the CNN Video Reports 3, 4, and 5 on volcanoes:

~~volcanic eruption~~
~~volcanic ash~~
~~Mount St. Helens~~

~~moonscape~~
~~climate changes~~
~~[illegible]~~

Mt. St. Helens Erupted in 1980 which caused great climate changes volcanic eruptions such as this one are destructive and some people say it looked like moonscape scientests thought volcanic ash was infertile but it was. The force of nature can never be predicted

CNN Video Report 6:
Hawaiians believe that Pele, the Goddess of Volcanoes, has a message for her people. What is the message?

respect each other

1-24-95
SUSAN.

CNN VIDEO REPORTS: FLAMINGO WATCH

CNN VIDEO REPORT	CAUSE *(The reason something has happened...)*	EFFECT *(What happened as a result of the cause...)*
ZEBRA MUSSEL INVASION	Different large boats are bringing them over when they stick to the bottom of the ~~boat~~ the.	They're cleaning the water so much that the fish don't have anything to eat & they're dying.
EXOTIC WATER WEEDS	People from Euope brought it over.	It is eating over water areas even the Nyle. It's hurting the different animals in the water & doesn't allow some boats

Use these words to write a summary of the CNN Video Reports 3, 4, and 5 on volcanoes:

~~volcanic eruption~~
~~volcanic ash~~
~~Mount St. Helens~~

~~moonscape~~
~~climate changes~~
~~force of nature~~

a big volcanic eruption happend at Mount St. Helens happen several years ago. When the eruption was over it looked like moonscape, desserted, bare. The climate changed & forces of nature did too. Now there →

CNN Video Report 6:
Hawaiians believe that Pele, the Goddess of Volcanoes, has a message for her people. What is the message?

The message she's giving is to be kind to eachother.

3

2-3-95

Dear Mrs. Brook,

I liked the flaming watch! Something I would like to learn more about is the baboons & how they're climbing over the fence. Something that amazed me was that the Wart Hogs could just charge through the electriet fences without being chocked. I liked how the hippos looked like big clumps of mud or rocks in the mud. I enjoyed learning how harmful the chemicles can be in the water. The soda water looks very harmless.

Your Pal,
Susan

2-3-95

Dear Mrs. Brook,

I like learning about the animal in Kenya, the soda lakes, and Nahuru Lake. I was amazed that the flamigo could stand in the soda water because they have very thik skin. I thout that it was exciting that two of [illegible] student had there questions answered.

A part that I enjoyed was when we compared Kenya to Michigan. I also enjoyed learning about flamingos where they live, how they build there nest and what they eat and how they eat the food.

Jackie

Application Essay

Susan
2-16-95

baboon
I want this animal
because when I was
watching CNN newsroom
I got intrested in
how they act and
how they are like
humans and how
there different. I would
like to know more
about the way they
live and what they
eat. They are very
interesting to learn
about these actions
from what I saw
in CNN newsroom.

REFERENCES

Ahlgren, A., Rutherford, F.J. May, 1993. Where is project 2061 today? Educational Leadership, 19-22.

Alty, J.L. 1993. Multimedia: We have the technology but do we have a methodology? Educational Multimedia and Hypermedia Annual. Charlottesville, VA: AACE.

American Association for the Advancement of Science. 1990. Science for all Americans. New York: Oxford University Press.

American Association for the Advancement of Science. 1993. Benchmarks for science literacy: Project 2061. New York: Oxford University Press.

America 2000. 1992. American education in a global context. Publishing information unknown.

Anderson, C.W. 1989. Policy implications of research on science teaching and teachers' knowledge. In (NCRTE) Competing visions of teacher knowledge: Proceedings from an NCRTE seminar for education policymakers. East Lansing, MI: NCRTE.

Arons, A.B. 1983. Achieving wider scientific literacy. Daedalus, 112 (2) 91-121.

Atkins, S.L. 1994. Creating images of model elementary school mathematics programs. Technology and Teacher Education Annual-1994. Charlottesville, VA.: AACE.

Baker, D.R. 1990. A summary of research in science education. Columbus, OH.: ERIC Clearinghouse for science, mathematics, and environmental education.

Ball, D.L. 1989. Teaching mathematics for understanding: What do teachers need to know about subject matter? In (NCRTE) Competing visions of teacher knowledge: Proceedings from an NCRTE seminar for education policymakers. East Lansing, MI: NCRTE.

Ball, D.L., McDiarmid, G.W. 1989. The subject matter preparation of teachers. East Lansing: National Center for Research on Teacher Learning.

Ball, D.L., Wilson, S.M. 1990. Knowing the subject and learning to teach it: Examining assumptions about becoming a mathematics teacher. East Lansing: National Center for Research on Teacher Learning.

Ball, D.L., Mosenthal, J.H. 1990. The construction of new forms of teaching: Subject matter knowledge in inservice teacher education. East Lansing: National Center for Research on Teacher Learning.

Banks, J.A. 1989. Social science knowledge and citizenship education. In (NCRTE) Competing visions of teacher knowledge: Proceedings from an NCRTE seminar for education policymakers. East Lansing, MI: NCRTE.

Bao, J.Q. 1994. ECSFE: A model for integrating software into method courses for preservice teachers. Technology and Teacher Educational Annual. Charlottesville, VA: AACE.

Bean, J. 1991 The middle school: The natural home of integrated curriculum. Educational Leadership, p. 9-13.

Becker, H. J. 1994. How our best computer using teachers differ from other teachers: Implications for realizing the potential of computers in schools. Journal of Research on Computing in Education, Vol. 26, Spring, 1994.

Beers, M.I. 1994. Integrating information technology into the elementary mathematics curriculum. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Beichner, R.J. Undated. A multimedia editing environment promoting science learning setting - A case study. Unknown source.

Benavot, Aaron. 1992. Curricular content, educational expansion, and economic growth. Comparative Education Review, vol. 36, no. 2. May 1992.

Bennett, D.A., King, D.T. May, 1991. The Saturn school of tomorrow. Educational Leadership, 41-44.

Berliner, D. 1986. In pursuit of the expert pedagogue. Educational Researcher, Vol 15, (7), 5-13.

Berliner, D. 1988. The development of expertise in pedagogy. Charles W. Hunt Memorial Lecture at the American Association of Colleges for Teacher Education: New Orleans, LA, February 17, 1988.

Bievenue, L., Farmer, C., Duban, J. 1993. The Internet express. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Birnie, H. 1991. Science in the schools. Saskatoon College: Saskatchewan, Canada.

Bogdan, R.C., Biklen, S.K. 1992. Qualitative research for education: An introduction to theory and methods. Boston: Allyn and Bacon.

Borman, K.M., LeCompte, M.D., & Goetz, J.P. 1986. Ethnographic and qualitative research design and why it doesn't work. American Behavioral Scientist. vol. 30 (1) pp. 42-57.

Bracey, G. September, 1992. Why some teachers use computers better than others. Electronic Learning, 12.

Brooks, J.G. & Brooks, M.G. 1993. In search of understanding: The case for constructivist classrooms. Alexandria, VA: ASCD.

Brown, G.R., Logan, J. 1993. Technology in the schools and the challenge of collaboration. Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Bruder, I. March, 1993. Redefining science: Technology and the new science literacy. Electronic Learning, 20-25.

Buchmann, M. 1984. The priority of knowledge and understanding in teaching. In L.G. Katz & J.D. Raths (Eds.). Advances in teacher education. Vol. 1. Norwood, NJ: Ablex.

Buchmann, M. 1987. Teaching knowledge: The lights to live by. East Lansing: National Center for Research on Teacher Learning.

Burkhouse, B. 1994. Aligning information technology with curricular intent. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Bybee, R.W. 1993. Reforming science education: Social perspectives & personal reflections. New York: Teachers College Press.

Campbell, D. 1993. Assertion/data assessment assignment. Notes issued in TE 995, East Lansing: Michigan State University.

Carleton, R. H. 1963. On scientific literacy. NEA Journal, vol 52, 33-35 and 57.

Casey, M.B., Tucker, E.C. October, 1994. Problem-centered classrooms: Creating lifelong learners. Phi Delta Kappan, 139-143.

Champagne, A.B. 1989. Science: Defining scientific literacy. Educational Leadership, 85-86.

Champagne, A.B., Newell, S.T. 1992. Directions for research and development: Alternative methods of assessing scientific literacy. Journal of Research in Science Teaching, 29 (8) 841-860.

Cochran, K.F., DeRuiter, J.A., and King, R.A. 1993. Pedagogical content knowing: An integrative model for teacher preparation. Journal of Teacher Education, 44 (4) 263-272.

Collins, A. 1990. Sheingold, K. & Tucker, M. (Eds.) The role of computer technology in restructuring schools. In Restructuring for learning with technology. New York: Bank Street College of Education.

Conference Series 89-1. 1989. Competing visions of teacher knowledge: Proceedings from an NCRTE seminar for education policymakers, February 24-26, 1989.

Connell, M.L. 1993. Technology enhanced cases. Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Connell, M.L. 1993. A constructivist use of technology in elementary mathematics. Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Copley, J.V. 1993. The use of technology in early childhood classrooms: A constructivist approach to teacher education. Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Couch, J.D., Couch, K., Peterson, A.J. 1993. Interdisciplinary study with computer based multimedia. Pittsburgh, PA: Annual Conference of Visual Literacy.

Cox, D.A.H. 1981. Early adolescent use of selected problem-solving skills using microcomputers. Doctoral dissertation, University of Michigan, 1980. Dissertation Abstracts International, 41, 3855A.

Cuban, L. 1984. Introduction. In How Teachers Taught. Publisher unknown.

Cuban, L. 1993. Computers meet classroom: Classroom wins. Teachers College Record, 95 (2) 185-210.

David, J.L. 1990. Sheingold, K. & Tucker, M. (Eds.) Restructuring and technology: Partners in change. In Restructuring for learning with technology. New York: Bank Street College of Education: New York.

Davis, N. 1994. Identifying and evaluating the benefits of educational telecomputing. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

DeBoer, G.E. 1991. A history of ideas in science education: Implications for practice. New York: Teachers College Press.

Dede, C. 1990. Sheingold, K. & Tucker, M. (Eds.) Current misconceptions about educational technology. In Restructuring for learning with technology. New York: Bank Street College of Education.

Dell, A.G., Disdier, A. 1994. Teaching future teachers to enhance teaching and learning with technology. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Draina, L.K. 1994. Technology in schools: A call for curriculum integration. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Driver, R., Asoko, H., Leach, J., Mortimer, E., Scott, P. 1994. Constructing scientific knowledge in the classroom. Educational Researcher, 23 (7) 5-12.

Duckworth, E. 1987. The having of wonderful ideas. New York: Teachers College Press.

Duckworth, E. 1988. In Broderick et al. (Eds.). For teachers about teaching. Cambridge, MA: Harvard Educational Review.

Dwyer, D.C., Ringstaff, C., Sandholtz, J.H. 1990. Teacher beliefs and practices part I: Patterns of change. Apple Classrooms of Tomorrow, Cupertino, CA: Apple Computer.

Dwyer, D.C., Ringstaff, C., Sandholtz, J.H. 1990. Teacher beliefs and practices part II: Support for change. Apple Classrooms of Tomorrow, Cupertino, CA: Apple Computer.

Dwyer, D.C., Ringstaff, C., Sandholtz, J.H. 1991. Changes in teachers' beliefs and practices in technology-rich classrooms. Educational Leadership. 45-52.

Editor. 1983. Preface to the issue: "Scientific literacy." Daedalus. 112 (2) v-vii.

ERIC. 1990. Selected procedures for improving the science curriculum. Columbus, OH: Clearinghouse for Science, Mathematics, and Environmental Education.

ERIC. 1990. Current projects and activities in K-12 science education curriculum development. Columbus, OH: Clearinghouse for Science, Mathematics, and Environmental Education.

Erickson, F. 1986. (Ed.) Wittrock, M.C. Qualitative methods in research on teaching. In Handbook of Research on Teaching, New York: Macmillan.

Feiman-Nemser, S. 1987. (Ed.) Teacher education and learning to teach: Proceedings of the first annual NCRTE retreat, June 24-26, 1987. East Lansing: National Center for Research on Teacher Learning.

Feiman-Nemser, S., Parker, M. 1990. Making subject matter part of the conversation or helping beginning teachers learn to teach. East Lansing: National Center for Research on Teacher Learning.

Feiman-Nemser, S. 1992. Introducing teaching. In S. Feiman-Nemser and H. Featherstone (Eds.), Exploring teaching: Reinventing an introductory course. New York: Teachers College Press.

Ferris, A., Roberts, N. 1994. Teachers as technology leaders: Five case studies. Educational Technology Review, (3), 11-18.

Fetters, M. 1994. Negotiation in a heterogenous high school biology classroom: Implications for special education students. A dissertation submitted to Michigan State University. East Lansing: Michigan State University.

Firestone, W.A. 1993. Alternative arguments for generalizing from data as applied to qualitative research. Educational Researcher, 22 (4) 16-23.

Flaste, R. 1991. The New York Times book of science literacy: What everyone needs to know from Newton to the knuckle ball. New York: Harper Perennial.

Floden, R.E., Clark, C.M. 1987. Preparing teachers for uncertainty. East Lansing: National Center for Research on Teacher Learning.

Freeouf, B., Flank, S. 1994. Preparing teacher educators to integrate technology into required courses: W.T.E.G. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Fulton, K. 1993. Teaching matters: The role of technology in education. Ed-Tech Review, Autumn/Winter, 1993.

Gallagher, J. 1971. A broader base for science teaching. Science Education, 55, 329-338.

Gallagher, J.. 1993. Tobin, K. (ed.) Secondary science teacher and constructivist practice. The Practice of Constructivism in Science Education, Hillsdale, NJ: Earlbaum.

Glaser, B., Strauss, A. 1967. The discovery of grounded theory. Chicago: Aldine.

Glynn, S.M., Muth, K.D. 1994. Reading and writing to learn science: Achieving scientific literacy. Journal of Research in Science Teaching, 31 (9) 1057-1073.

Gold, R. L. 1969. Roles in sociological field observations. In G. J. McCall and J. L. Simmons (Eds.), Issues in participant observation: A text and reader. Reading, MA: Addison-Wesley Publishing Company.

Grejda, G.F., Smith, K.A. 1994. The nineties teacher locked into the seventies classroom. Technology and Teacher Education Annual, Charlottesville, VA: AACE.

Grossman, P. L. 1990. The making of a teacher: Teacher knowledge and teacher education. New York: Teachers College Press.

Gurney, B.F. 1995. Tugboats and tennis games: Preservice conceptions of teaching and learning revealed through metaphors. Journal of Research in Science Teaching, 32 (6) 569-583.

Hall, R.T. 1993. What is computer literacy for a mathematics teacher? Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Hamm, M. 1992. Achieving scientific literacy through a curriculum connected with mathematics and technology. School Science and Mathematics, 92 (1) 6-9.

Harlow, S., Maddux, C.D., Johnson, L. 1994. World literacy: An alternative for the schools. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Harrington, H.L., Quinn-Leering, K. 1994. Computer conferencing, moral discussion, and teacher development. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Hawkins, D. 1974. I, Thou, It. The informed vision: Essays on learning and human nature. New York: Agathon Press.

Hawkins, D. 1983. Nature closely observed. Daedalus, 112 (2) 65-89.

Hazen, R.M., Trefil, J. 1991. Science matters: Achieving scientific literacy. New York: Doubleday.

Heath, S.B. 1983. Ways with words: Language, life, and work in communities and classrooms. Cambridge: Cambridge University Press.

Hill, M. 1992. The new literacy: No longer is it enough just to read and write. Electronic Learning, 28-31.

Hofmeister, A., Carnine, D., Clark, R. 1994. A blueprint for action: Technology, media, and materials. (draft). Washington D.C: American Association for the Advancement of Science.

Householder, D.L. 1992. Cross-curriculum problem solving. In G. Hauber, L. Litowitz, and J. McCade (Eds.). Technology education symposium XIV: Teaching problem solving versus content in technology education. Millersville, PA: Millersville University.

Hunt, N.P. 1994. Intentions and implementations: The impact of technology coursework in elementary classrooms. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Hurd, P.D. 1969. Science literacy: Its meaning for American schools. Educational leadership, 16 (1), 13-16 and 52.

Hurd, P.D. 1970. scientific enlightenment for an age of science. The Science Teacher, 37 (1) 13-14.

Hurd, P.D. 1972. Emerging perspectives in science teaching for the 1970's. School Science and Mathematics, 72 (3) 22-28.

Hurd, P.D. 1984. Reforming science education: The search for a new vision. Washington D.C.: council for Basic Education.

Itzkan, S.J. 1994. Assessing the future of telecomputing environments: Implications for instruction and administration. The Computing Teacher, Dec/Jan 1994-95.

Jackson, P.W. 1983. The reform of science education: A cautionary tale. Daedalus. 112 (2) 143-163.

Jackson, P.W. 1986. The pracice of teaching. New York: Teachers College Press.

Jackson, D.F., Doster, E.C., Tippins, D.J. Rutledge, M.L. 1994. Implementing "real science" through microcomputers and telecommunications in project-based elementary classrooms. Journal of Science Education and Technology, 3 (1) 17-26.

Jafari, A. 1993. Putting together the multimedia electronic classroom. Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Jenkins, E.W. 1992. School science education: Towards a reconstruction. Journal of Curriculum Studies, 24 (3) 229-246.

Jenkins, E.W. 1994. Public understanding of science and science education for action. Journal of Curriculum Studies, 26 (6) 601-611.

Johnson, L., Maddux, C., Harlow, S. 1994. Technology and education: A successful marriage for the twenty-first century. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Kay, A. 1991. Computers, networks, and education. Scientific American. p. 138-148.

Kennedy, M. 1989. Preface. In (NCRTE) Competing visions of teacher knowledge: Proceedings from an NCRTE seminar for education policymakers. East Lansing, MI: NCRTE.

Kepner, H.S. 1994. Teacher teams integrating technology into the mathematics/science curriculum. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Koelsche, C.L., Morgan, A.G. 1964. Scientific literacy in the Sixties. University of Athens, GA: Georgia Printing Office.

Kohl, H. 1984. Growing minds: On becoming a teacher. New York: Harper Colophon.

Kortecamp, K., Croninger, W. 1994. Enhancing the integration of technology in preservice teacher education through building a technology classroom. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Kyle, W.C. 1995. Scientific literacy: How many lost generations can we afford? Editorial Part I. Journal of Research in Science Teaching, 32 (9) 895-896.

Kyle, W.C. 1995. Scientific literacy: Where do we go from here? Editorial Part II. Journal of Research in Science Teaching, 32 (10) 1007-1009.

Lacy, T.W. 1987. In Tobin and Fraser (Eds.) Exemplary primary science teaching. Exemplary practices in science and mathematics education. Perth, Western Australia: Curtin University of Technology.

Lederman, N.G., Gess-Newsome, J. & Zeidler, D. 1993. A summary of research in science education 1991. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Lewis, T., Gagel, C. 1992. Technological literacy: A critical analysis. Journal of Curriculum Studies, 24 (2) 117-138.

Lincoln, Y.S. & Guba, E.G. 1985. Naturalistic inquiry. Newbury Park, CA: Sage.

Lomisar, B.P., McClellan, J.E. (Eds.) Smith, O. & Ennis, R. 1961. "The logic of slogans" in Language and concepts in education. Chicago: Rand McNally and Company.

Lortie, D.C. 1975. Schoolteacher: A sociological study. Chicago: The University of Chicago Press.

McCarthy, R. April, 1993. A computer on every teacher's desk. Electronic Learning, 10-14.

McComas, W.F. 1996. Ten myths of science: Reexamining what we think we know about the nature of science. School Science and Mathematics, 96 (1), 10-16.

McDiarmid, G.W., Ball, D.L., and Anderson, C.W. 1989. Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. East Lansing: National Center for Research on Teacher Learning.

McDiarmid, G.W. 1990. Tilting at webs of belief: Field experiences as a means of breaking with experience. East Lansing: National Center for Research on Teacher Learning.

McDiarmid, G.W. 1992. The arts and sciences as preparation for teaching. East Lansing: National Center for Research on Teacher Learning.

McDiarmid, G.W. 1995. Realizing new learning for all students: A framework for the professional development of Kentucky teachers. East Lansing: National Center for Research on Teacher Learning.

McQuillan, P. 1994. Computers and pedagogy: The invisible presence. Journal of Curriculum Studies, 26 (6) 631-653.

McPherson, S. 1993. Computers in science: A school-based training program for applying technology to the elementary science curriculum. Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Maarschalk, J. 1988. Scientific literacy and informal science teaching. Journal of Research in Science Teaching, 25 (2) 135-146.

MacIsaac, D.L. 1994. Curricular reformation in computer-based undergraduate physics laboratories via action research. Ph.D. dissertation. West Lafayette, IN: Purdue University.

Maddux, C., Johnson, L., Harlow, S. 1994. Educational computing: Avoiding the Everest Syndrome in the 21st century. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Martin-Kniep, G.O., Uhrmacher, P.B. 1992. Teachers as curriculum developers. 24 (3) 261-271.

Marzano, R.J. 1992. A different kind of classroom: Teaching with dimensions of learning. Alexandria, VA: Association for Supervision and Curriculum Development.

Mason, M. 1994. The problem solving corner: An electronic community of math learners. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Max, D.T. 1994. The end of the book? Atlantic Monthly, p 61-71.

Maxwell, J.A. 1992. Understanding and validity in qualitative research. Harvard Educational Review, vol. 62, (3) 279-300.

Maykut, P., Morehouse, R. 1994. Beginning qualitative research: A philosophic and practical guide. Bristol, PA: The Falmer Press.

Meier, S.L., Houde, R.L., Meier, R.L. 1996. Problem solving: Teachers' perceptions, content area models, and interdisciplinary connections. School Science and Mathematics, 96 (5) 230-237.

Michigan Department of Education. 1991. Michigan Essential Goals and Objectives for K-12 Science Education. Lansing, MI: Michigan State Board of Education.

Miller, J.D. 1983. Scientific literacy: A conceptual and empirical review. Daedalus, 112 (2) 29-47.

National Research Council. 1996. National science education standards . Washington D.C.: National Academy Press.

Nemeth, E.J. 1993. Grassroots telecommunications: An alternative teacher education resource. Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Novelli, J. October, 1993. There's never been a better time to use technology. Instructor, 34-43.

Oldfather, P., West, J. 1994. Qualitative research as jazz. Educational Researcher. 23 (8) 22-26.

Osborne, R., Freyberg, P. 1985. Roles for the science teacher. In Learning in science: The implications of children's science. Auckland, NZ: Heinemann.

Palincsar, A.S., Anderson, C. & David, Y. 1993. Pursuing scientific literacy in the middle grades through collaborative problem solving. The Elementary School Journal, 93 (5) 643-658.

Pan, A.C. 1994. Customizing technology in the classroom for preservice educators. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Papert, S. 1993. The children's maching: Rethinking school in the age of the computer. New York: Basic Books.

Penick, J.E., Yager, R.E. 1983. The search for excellence in science education. Phi Delta Kappan, (64), 621-623.

Peshkin, A. 1993. The goodness of qualitative research. Educational Researcher, 22 (2) 24-30.

Philips, E.R., Uprichard, A.E. 1989. Preparing elementary teachers to teach mathematics. In (NCRTE) Competing visions of teacher knowledge: Proceedings from an NCRTE seminar for education policymakers. East Lansing, MI: NCRTE.

Prewitt, K. 1983. Scientific illiteracy and democratic theory. Daedalus, 112 (2) 49-64.

Raizen, S., Michelson, A. 1994. The future of science in elementary schools: Educating prospective teachers. SanFrancisco: Jossey-Bass Publishers.

Ravitch, D. 1983. The troubled crusade: American education, 1945-1980. New York: Basic Books, Inc., Publishers.

Reid, T. R. July, 1995. Kobe wakes to a nightmare. National Geographic, 112-136.

Roberts, D.A. 1983. Scientific literacy: Towards balance in setting goals for school science programs. Ottawa: Science Council of Canada.

Roberts, P.L., Kellough, R.D. 1996. A guide for developing an interdisciplinary unit. Englewood Cliffs, NJ: Merrill.

Rowe, M.B. 1983. Science education: A framework for decision-makers. Daedalus. 112 (2) 123-141.

Rubba, P.A. 1987. Perspectives on science-technology-society instruction. School Science and Mathematics, 87 (3) 181-185.

Rush, M.J. 1993. Breaking down barriers through telecommunications. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Sanche, R., Haines, L., Robertson, G. 1993. AIMS CoPlanner: Computer technology supporting collaborative decision-making across the curriculum. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

Scheffler, I. 1965. The language of education. Springfield, IL: Charles C. Thomas.

Schmidt, W.H., Kennedy, M.M. 1990. Teachers' and teacher candidates' beliefs about subject matter and about teaching responsibilities. East Lansing: National Center for Research on Teacher Learning.

Schon, D. 1983. The reflective practicioner. New York: Basic Books.

Schulman, J.H. 1990. Now you see them, now you don't: Anonymity versus visibility in case studies of teachers. Educational Researcher, 19 (6) 11-15.

Schuttloffel, M.J. 1994. The technology integrated classroom and implications for teacher education: A cautionary story. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Shamos, M. H. 1995. The myth of scientific literacy. New Brunswick, NJ: Rutgers University Press.

Sheingold, K. 1990. Sheingold, K. & Tucker, M. (Eds.) Restructuring for learning with technology: The potential for synergy. In Restructuring for Learning with Technology. New York: Bank Street College of Education.

Sheingold, K., Hadley, M. 1990. Accomplished teachers: Integrating computers in classroom practice. New York: Bank Street College of Education. Center for Technology in Education.

Shen, B. 1975. Science literacy: The public need. The Sciences, 24 (6) 27-28.

Shulman, L.S. 1986. Those who understand: Knowledge growth in teaching. Educational Researcher. February, 1986. 4-14.

Shulman, L.S. 1987. Knowledge and teaching: Foundations of the new reform. Harvard Educational Review. 57 (1) 1-22.

Siegel, J. 1995. The state of teacher training: The results of the first national survey of technology staff development in schools. Electronic Learning, 43-54.

Smith, N.F. 1974. The challenge of scientific literacy. The Science Teacher, 41 (6) 34-35.

Solomon, G. April, 1993. Teachers who use technology. Electronic Learning, 16-19.

Solomon, J., Aikenhead, G., (Eds.) 1994. STS education: International perspectives on reform. New York: Teachers College Press.

Stahlhut, R.G. 1994. Technology: Connecting people and places. Technology and Teacher Education Annual, Charlottesville, VA: AACE.

Sternberg, R.J., Horvath, J.A. 1995. A prototype view of expert teaching. Educational Researcher, 24 (6) 9-17.

Stevenson, H. W., Stigler, J. W. 1992. The learning gap: Why our schools are failing and what we can learn from Japanese and Chinese education. New York: Simon & Schuster.

Strudler, N.B. 1994. A tale of computer use at three elementary schools: Implications for teacher educators. Technology and Teacher Education Annual, Charlottesville, VA: AACE.

Swan, K., Mitrani, M. 1993. The changing nature of teaching and learning in computer-based classrooms. Journal of Research on Computing in Education. 26 (1) 40-53.

Thier, H., Nagle, B. 1994. In Solomon and Aikenhead, (Eds.). Developing a model for issue-oriented science. New York: Teachers College Press.

Tobias, S. 1990. They're not dumb, they're different: Stalking the second tier. Tuscon, AZ: Research Corporation.

Tobin, K., Fraser, B. (Eds.) 1987. Exemplary practices in science and mathematics education. Perth, Western Australia: Curtin University of Technology.

Tobin, K., Fraser, B. 1989. Case studies of exemplary science and mathematics teaching. School Science and Mathematics, 89 (4), 320-331.

Tobin, K., LaMaster, S.U. 1995. Relationships between metaphors, beliefs, and actions in a context of science curriculum change. Journal of Research in Science Teaching. 32 (3) 225-257.

Viau, E.A. 1994. The mind as a channel: A paradigm for the information age. Educational Technology Review, (3), 5-10.

Waks, L.J., Barchi, B.A. (Ed.) Aikenhead, G. 1992. STS in U.S. school science: Perceptions of selected leaders and their implications for STS education. Science Education, 76 (1) 79-90.

Walker, D. 1990. Fundamentals of curriculum. New York: Harcourt Brace Jovanovich.

Wasserman, S. April, 1994. Using cases to study teaching. Phi Delta Kappan, 602-611.

Waxman, H.C., Huang, S.Y.L. 1993. Investigating computer use in elementary and middle school inner-city classrooms. Technology and Teacher Education Annual-1993. Charlottesville, VA: AACE.

Waxman, H.C., Padron, Y.N. 1994. Alternative models for evaluating technology-enriched professional development schools. Technology and Teacher Education Annual. Charlottesville, VA: AACE.

White, J.A. 1994. Modern instructional technology and concepts of curriculum. Technology and Teacher Education Annual-1994. Charlottesville, VA: AACE.

Wilcox, S.K., Schram, P., Lappan, G., Lanier, P. 1991. The role of a learning community in changing preservice teachers' knowledge and beliefs about mathematics education. East Lansing: National Center for Research on Teacher Learning.

Wilson, S.M. 1989a. A case concerning content: Using case studies to teach subject matter. East Lansing: National Center for Research on Teacher Learning.

Wilson, S.M. 1989b. Parades of facts, stories of the past: What do novice history teachers need to know? In (NCRTE) Competing visions of teacher knowledge: Proceedings from an NCRTE seminar for education policymakers. East Lansing, MI: NCRTE.

Wilson, S. M. 1992. Thinking about teaching, teaching about teaching. In S. Feiman-Nemser and H. Featherstone (Eds.), Exploring teaching: Reinventing an introductory course. New York: Teachers College Press.

Wilson, S. M., Shulman, L.S., & Richert. A.E. 1987. 150 different ways of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), Exploring teachers' thinking. London: Cassell.

Wolcott, H.F. 1990. On seeking-and rejecting-validity in qualitative research. In E.W. Eisner & A. Peshkin (Eds.), Qualitative inquiry in education: The continuing debate. New York: Teachers College Press.

Wolcott, H.F. 1992. Posturing in qualitative inquiry. In The handbook of qualitative research in education. M.D. LeCompte, W.L. Millroy, and J. Preissle, Eds. pp. 3-52. San Diego: Academic Press.

Yager, R.E. 1990. The science-technology-society movement in the United States: Its origin, evolution, and rationale. Social Education, 196-201.

Yager, R.E. 1993. Science-technology-society as reform. School Science and Mathematics, 93 (3) 145-151.

Yin, R. K. 1989. Case study research: Design and methods. Newbury Park, CA: Sage.

Yin, R. K. 1993. Applications of case study research. London: Sage Publications.

Ziman, J. 1994. In Solomon and Aikenhead, (Eds.). The rationale of STS education is in the approach. New York: Teachers College Press.