University of Alberta

# The Questions of Scientific literacy and the Challenges for Contemporary Science Teaching: An Ecological Perspective

by

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# ABSTRACT

This study began with questions about how science education can bring forth humanity and ethics to reflect increasing concerns about controversial issues of science and technology in contemporary society. Discussing and highlighting binary epistemological assumptions in science education, the study suggests embodied science learning with human subjectivity and integrity between knowledge and practice. The study questions a) students' understandings of the relationships between STSE and their everyday lifeworld and b) the challenges of cultivating scientific literacy through STSE teaching. In seeking to understand something about the pedagogical enactment of embodied scientific literacy that emphasizes the harmony of children's knowledges and their lifeworlds, this study employs a mindful pedagogy of hermeneutics. The intro- and intra-dialogical modes of hermeneutic understanding investigate the pedagogical relationship of parts (research texts of students, curriculum, and social milieu) and the whole (STSE teaching in contemporary time and place). The research was conducted with 86 Korean 6 graders at a public school in Seoul, Korea in 2003. Mixed methods were utilized for data collection including a survey questionnaire, a drawing activity, interviews, children's reflective writing, and classroom teaching and observation.

The research findings suggest the challenges and possibilities of STSE teaching as follows: a) children's separated knowledge from everyday practice and living, b) children's conflicting ideas between ecological/ethical aspects and modernist values, c) possibilities of embodied knowing in children's practice, and d) teachers' pedagogical dilemmas in STSE teaching based on the researcher's experiences and reflection throughout teaching practice. As further discussion, this study suggests an ecological paradigm for science curriculum and teaching as a potential framework to cultivate participatory scientific literacy for citizenship in contemporary science teaching.

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나의 꿈과 이상을 인내, 사랑, 그리고 확신으로 함께 이끌어 준 내 가족들에게 감사드립니다. 그들의 존재와 이해가 없이 오늘의 이 결과는 불가능하였을 것 입니다.

사랑하는 내 가족들, 특히 아버지의 영혼과 어머니의 사랑에 이 논문을 바칩니다.

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# INTRODUCTION & OVERVIEW

Recently, I have wondered about what Einstein's $E=mc^2$ means to us as science teachers in this time and place, where the complexity of nuclear power and weapons issues often invokes public attention around the world. When, as a student, I learned it as a formula to calculate the amount of energy created in nuclear reactions, it could be understood simply as a matter of correct answers to calculations with numbers. Regardless of its productive and destructive implications for human lives, the formula and the numbers seemed always to be neutral, objective, and reliable. Human beings who have lived through - and will continuously live with - these issues are not considered part of the content of science, thus their lives remain unrecognized and unsaid in science classrooms.

In science, we teach *the thing* of science with objectified minds, leaving the lifeworld behind us 'for now', expecting that there will be another time and another place in which to talk about it. As science teachers with good knowledge and sound practice, we are focused and faithful to our students and curriculum. What else do we need to become "good" science teachers?

Over the years, I have been interested in the relationship of science curriculum and teaching to human ethics and ecological interrelationships. With growing numbers of controversial issues in relation to science and technology around the world, I have been concerned about the consequences of those issues. As a teacher, I ponder our pedagogical responsibility to bring humanity into science classrooms. It has been an on-going dilemma for me, however, to contextualize human values and ecological interconnectedness within the positivistic discourses of western science that are so deeply entrenched in our modern minds.

As one who has grown up in Korea, I struggled to learn how to understand the meanings of eastern ideals, values, and ways of life in the context of western science and education. My ideas sometimes appeared to those with objectified modernist scientific minds as the romanticized views arising from Eastern philosophy, and thus, not realistic or acceptable. But these struggles have helped me to know the importance of my own background and tradition in helping me to see the places I intend to go and the person I am becoming. My dissertation is a mindful response to my on-going struggles to find harmony among myself, children, and forms of science education that embrace ethical and ecological perspectives.

The dissertation consists of six parts

I. The research position (Chapter 1),
II. Scientific literacy and issues of S-T-S (Science-Technology-Society) (Chapters 2 and 3),
III. Epistemological assumptions of science: Binary understanding vs. embodied knowledge (Chapters 4 and 5),
IV. Research rationale and methods (Chapters 6 and 7),
V. Research findings and reflections (Chapters 8, 9, and 10), and
VI. Considerations for science teacher education (Chapter 11).

The themes of each chapter are as follows:

In Chapter 1, I introduce the topic of the relationships among science, technology, society, and the environment, sharing my memory of a 'lost' river from my childhood. The story begins the process of weaving together my understandings of science, education, Korean society, and the world in the context of today's science curriculum. This chapter is intended to introduce the major themes of the dissertation.

Chapter 2 discusses current discourses around scientific literacy, one of the main objectives espoused by modern science curricula. I explore the multiple interpretations of, and approaches to, scientific literacy that are described in the science education literature. Science-Technology-Society-the Environment (STSE[1]) curricula have been introduced as a way of cultivating scientific literacy and attending to the participatory implications of knowledge. Efforts to promote scientific literacy, however, have not delivered effective empowerment of the participatory dimensions of scientific knowledge nor have they facilitated the implementation of STSE curricula in our classroom practice. This chapter suggests that to consider problems and issues around scientific literacy, it might be necessary for us to challenge conventional approaches to scientific literacy and STSE curriculum with different visions and directions.

In Chapter 3, I approach the notion of scientific literacy through examining the ambiguous epistemologies of science that have indoctrinated our ways of learning and teaching science. Challenging many science educators' belief in the objectivity and absolute truth of scientific knowledge, this chapter discusses the uncertainty of scientific knowledge. It also examines the essence of technology, discussing the relationships between human agency and modern technology. In light of the social dimensions of science and technology, scientific knowledge cannot be separated from

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[1] Science-Technology-Society (STS) and Science-Technology-Society-the Environment (STSE) can be used alternately in the same context. Recently, STSE is being used more often to bring forth the awareness of environmental issues. STSE education will be explained more in detail in next chapter.

human relationships. From those understandings, this chapter attempts to challenge objective and positivistic views of science to discuss the cultivation with our students, the culivation of a form of scientific literacy that recognizes the connections between science, technology, and life.

Chapter 4 continues to critique the ways in which our teaching practices have perpetuated the notion of pure objectivity in scientific knowledge. When science teachers devalue human subjectivity, scientific knowledge becomes fragmented and students' learning becomes disembodied. Pondering this separation between 'objective' knowledge and learning subjects, this chapter elucidates an argument for a form of scientific literacy that has as its goal the integration of knowledge and action through embodied learning. Chapter 4 emphasizes that students need to learn how to situate their subjective relationships within scientific contexts through embodied learning.

Binary understandings (subject/object, subjective/objective, mind/body) engendered by science teaching have brought not only divisions between objective knowledge and subjective understanding but also between knowledge and action. These binary conceptions are used to justify the idea that knowledge is neutral and conceptual, and that therefore, knowledge implies no concern with the consequence of knowing and the ethical implications of knowledge. As a certain notion I contrast this with the traditions of ethical knowing embedded in Confucian notion of *Cheng,* which emphasizes the integrity of knowing and doing, in Chapter 5. Knowledge, when understood as embodied human cognition, bears within itself an ethical responsibility to action. This junction between knowing and doing is where the ethics of knowing emerges and takes its integral place in humanity.

Understanding the issues of the embodiment of knowledge and the connection between scientific knowledge and human life world, it is critical for me to learn how to practice a 'pedagogy of mindfulness'. With enhanced attunement to time and place, I learn to create and sustain my pedagogical relationships with children in order to teach science in ecological ways. "Mindful pedagogy" emerges, not from isolation and passive understandings *about* children, but from attentive and dialogical interactions *with* children. An approach to a mindful pedagogy of science teaching may be found in hermeneutic understandings and commitments, which my research design and methods are based on.

Using a hermeneutic approach, in Chapter 6 I explore how my horizons as a researcher are interrelated with the research questions and research texts.

In Chapter 7, I explain the details of the research methods I employ and the contexts of children, science curriculum, school, and society in the context of a sixth grade classroom in Korea.

In Chapter 8, I analyze that data to explore the students' understandings of science and technology in their everyday lives. Through dialogue and interpreting research texts, I probe the complexity of children's understandings of STSE relationships in contemporary society.

Based on the findings of children's STSE understandings, I plan and conduct STSE teaching in the Grade 6 science classroom, which is discussed in Chapter 9. This part of the research was intended to explore the possibilities and difficulties of teaching an STSE curriculum through my practice and reflection.

Chapter 10 presents my reflections on the research process of exploring and developing a paradigm for ecological[2] science curriculum and teaching. In

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[2] In the public domain, the term ecology has been discussed as a holistic approach to understanding our relationships to the natural environment, whereas in science studies it is a science of living organisms. When the terms 'ecology' and 'environmentalism' have been used interchangeably in the public domain, misconceptions and confusion have resulted (Mazzotti, 2001, Available at http://edis.ifas.ufl.edu/UW150 #FOOTNOTE_1#FOOTNOTE_1). The distinction between ecology as science and environmentalism as social and political action is useful for us to understand the two different approaches: scientific knowledge and social movements concerned with preserving the natural world. Yet this distinction should not separate scientific knowledge (ecology) from the responsibility of knowing and action

hermeneutic inquiry, the interactive relationships between the researcher and the researched not only influence the research orientation and process but also greatly transform the researcher herself. I reflect on this personal transformation in Chapter 10.

Chapter 11 is a further reflection on scientific literacy and STSE education for science teacher education, addressing the binary understandings in science teaching. I suggest the development of ecological paradigm of science teaching, which re-situates science teaching within a relationship among students' lives, scientific literacy, and life connections as citizens of the world. It is suggested that science teacher education can be enhanced by challenging taken-for-granted positivistic views of science and traditional ways of science teaching in order to cultivate an ecologically-based scientific literacy.

Ecologically-based scientific literacy in my work understands scientific knowledge is nested in the grand scheme of life knowledge which is concerned with our sustainable and humanistic relationships to this world. When scientific literacy is

(environmentalism). In other words, ecologists need to know the complexity of knowledge and acting in social and political agendas and environmentalists need to understand scientific knowledge to make their action more grounded, appropriate, and empowered. In this sense, the integration of ecology as scientific knowledge and sociopolitical action is crucial. Therefore, in my work, I take the term 'ecological' or 'ecology' as a metaphor to discuss an embodied, interrelated, and situated framework of scientific knowledge and science eudcation in our life worlds.

embraced in the framework of the lifeworld, the separations of objectivity and subjectivity, knowledge and action, and human being and nature can no longer be acceptable. We as knower and actor are together responsible for science knowing and world making. Based on this understanding, this chapter takes into consideration how we take into account the responsibility of being and living as teacher to cultivate ecologically-based scientific literacy in our classroom practice.

# I

## THE POSITION OF RESEARCH

This section shares the story of a river from my childhood in order to begin an explanation of questions and issues relating to scientific literacy in contemporary society. Through the story, this section will explain how I have come to understand my own being as a teacher and researcher in the field of the relationships of science, technology, society, and the environment.

# CHAPTER 1

## A PERSONAL JOURNEY INTO THE PROBLEMATICS OF CONTEMPORARY SCIENCE EDUCATION

### Introduction

I wonder how I became interested in the idea that we science educators can do something *more* and something *different* in contemporary society. It is not that I think we need to teach more 'content', or different concepts of scientific knowledge. My concern is neither a matter of adding more knowledge or skills nor of reforming the structure of curriculum revolutionarily. I am concerned rather with developing a more mindful manner of thinking and questioning in relation to the current issues of science education.

In my previous science classrooms I wanted to learn more and teach more so that I could excel in what I was doing. I tried not to miss anything. Yet I was far from understanding the presence of science in life contexts. I did not realize that it was not only content knowledge that I was missing but an understanding of the 'meaning' of knowledge, which had its implications in our lifeworld.

Over time, my understanding of scientific knowledge has grown in the context of human relationships through my journey from Korean science classrooms to explore

Canadian and global contexts of science education. The journey has widened and deepened my concerns about the issues of modern science and technology locally and globally and expanded my vision of science education for our shared time and place. I have come to question how science education can bring forth the meaningfulness of knowledge into its mindful practice. I also question what my science teaching means in relation to the time and place that are vividly unfolding in front of us. With those questions, the journey (of my personal growth and learning and the resulting research – a journey this dissertation recapitulates) began by revisiting my memories of science learning and teaching, which have enlightened me to understand who I am, where I am, and where I need to go.

In this chapter I begin the process of unfolding a story of this journey as a way of opening my discussion of knowledge, science, and life in our time and place.

## The journey begins

### *Lost connections to science*

> Understanding comes through suffering.
>
> - Aeschylus (as quoted in Fisher, 2002, p. 188)

My story is about a river in my childhood - one about which I am greatly nostalgic[3]. Some say that we all feel nostalgic about our childhood memories of special places. They would say that as time goes by, we get older and miss certain things in our past. However, my nostalgia about the river is somewhat different. It involves not only yearnings but also much confusion and grief.

I tried to ignore the memory of the river. I pretended that I had seen nothing, felt nothing and known nothing about it. However, the memory haunted me with its voice. Over time, I saw my memory turning into frustration, sadness, and even anger. I tried to listen to the voice to find a way to let it out. I started writing about the experience. I remember my teacher's comment on my 'river story' three years ago. He said, *"This conflict suffering is precisely your story. Remember the comment – you wouldn't be Mijung without this conflict."* This comment has stayed with me since then.

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3 Nostalgia is a wistful or sentimental yearning for the past or irrevocable. It sometimes means also homesickness. To elaborate nostalgia etymologically, nostos is from ancient root nes- , which means return home and the suffix –algia is from algos, which means pain (Klein, 1979, p. 500). According to the Oxford dictionary, nostalgia is a "sentimental longing or wistful affection for a period in the past" (2002, p. 972). When nostalgia was first used in European languages, it was used as a medical term, denoting homesickness as a debilitating disease which accompanied physical symptoms such as nausea, loss of appetite or even severe hallucinations. "However, as the term "nostalgia" was adopted into other languages and entered common parlance, its meaning transformed. Instead of denoting a determinate and curable disease, "nostalgia" came to denote an indeterminate and incurable psychological malaise" (Burch, 2000).

Thich Nhat Hanh (1999) writes "we need suffering to see the path…If we are afraid to touch our suffering, we will not be able to realize the path of peace, joy and liberation. Don't run away. Touch your suffering and embrace it. Make a peace with it" (p. 45). I realized that avoidance or negligence would not be the way to alleviate my confusion. I needed to understand and live through it. So I embarked on my journey to meet my self in the conflict.

***The memory of the river***

*My hometown is in the southern part of Korea, which has beautiful mountains and a river. As a child, I spent most of my time outside playing with my sisters and friends. I loved the mountainside in the early spring. The trees, the streams, the wind, the rain, the sky, the sunshine, the rocks, and the smell of the dirt… I remember those days so vividly in my heart.*

*I loved to play near the river during the summer. In scorching summer days, the mirror-like water was so tempting. The sounds of the stream, the sparkling sunshine and the coldness of the water invited us all the time. We were happy watching fish,* *swimming and collecting pebbles along the side of the river. My joys and dreams for the world were growing up with my body.*

*The whole country in the 1970s was enthusiastic about developing the economy through industrialization. We believed it would lead us into a better world like Western developed counties. The fabric export industrial complex was built in the town. And the river began dying because of chemical toxins from the factories. On the other hand, some villagers were getting rich. They sold their land and got jobs in the plants. My family moved to Seoul and my river became only a place in my memory. Then one day, my family planned to visit my uncle who was still living in the town. The night before, I couldn't sleep. All my laughter, sunshine, and sparkling water were evoked. I was so excited to get to see the river again. I was 12 years old.*

*I went to see the river. But the water had dried up in the small creek in which I used to catch fish and splash. Instead, the river was full of black and oily scum, all over the sides and bottom. I smelled awful sewage. No water, no fish, no water weeds, no children, nothing but garbage and scum. I stood still at a loss. I lost the dreams and hopes of my childhood in that black, smelly and oily river. I was being told that we students needed to study hard the subjects "Science and Mathematics" because science* *and technology would be the keys to wonderful developments in not only each individual's life but also our nation's affluence in a coming international era. I loved the curious structures of mathematics and the mysterious phenomena of the universe. However, my river in childhood visited me from time to time and I didn't know what it was all about. I was struggling.*

*What is science for? Is it all about developing scientific knowledge to fulfill the nation's economic goals? The fact that we couldn't use the river in science classes any longer – or even enjoy it – became a big concern to me.*

Yu (1995) indicates that in Korea, a developing country with limited natural resources, "the government recognized from an early date (1960s) the role of science and technology as a crucial underpinning of industrial development" (p. 85). He also states that to enhance its productive economic capability in an international market, Korea focused on an industrial, high-technology strategy. This might have been a necessary choice to overcome the aftermath of the Korean War in the 1950s. And yet, I question whether or not the destruction of nature was an unavoidable result of scientific and technological developments. Is development *supposed* to come about at the expense of the natural environment and humanistic ways of living? What is meant by 'development' in modern society?

With this conflict in my mind, I explored various ideas of science curriculum and teaching through my graduate work. I questioned how we had learned and taught science in the middle of the current problems of modern science and technology. There was a great gap between scientific knowledge and the human lifeworld. I wondered how science education could reconcile the separated links between scientific knowledge and life with our critical minds. However, those questions seemed only peripheral in a situation where social and political demands greatly influenced and perhaps even determined the visions of science education and our classroom teaching. Moreover, in modern society where science and technology have been taken as tools for economic growth and political competition and school science potentially becomes a pawn of the socioeconomic strategy to produce more profits and human capital (Drori, 2004; Smith, 2002, 2003 a; Spring, 1998), my questions became more challenging and even seemed impossible.

In the classrooms, science educators face the challenge of finding ways to teach more productively and profitably. Teaching science with humanity and sustainability is not considered efficient or competitive enough for global society. The presence of students' human-ness is marginalized and forgotten. This notion is a global phenomenon, which many science teachers face in many different regions of the world today. I believe that I have developed a richer understanding of the relationships between science education and the competitiveness of global society as a result of my border crossings (Giroux, 1992) between Korean science classrooms and the North American contexts of science education.

From these understandings, I recognize that the loss of the river is not solely a local phenomenon of industrialization but a complex issue of science, society, and the environment in a global scheme. And I understand why science classrooms could not and did not answer my confusion in relation to the conflict between what I learned in science classroom and what I experienced outside the classroom. The national science curriculum could not see, and did not enable me to explore, the connection between science and students' everyday lives. As I struggled to find my lost river in relation to science and education, I became aware of the importance of science curriculum that is richly embedded in life contexts to rehabilitate the lost connections between scientific knowing and human relationships. I became interested in modes of science teaching that were enriched with humanity and helped teachers and students to develop the necessary mindfulness to be and live in this shared world.

These understandings and struggles around the river, science learning, society, and human lifeworld have opened my research questions to investigate possible ways to bring forth humanity and ethics in science education in contemporary society. I attempt to examine the following questions through my reserach:

1) What are children's understandings of the roles and relationships of science, technology, society, and the environment in their everyday lives?

2) How can ecological ways of teaching promote the relationships between scientific knowledge and students' everyday lives, and promote responsible decision making and action?

3) What are the challenges of STSE teaching?

The quest to understand what science education means for the 21st century has been challenging. There are so many different voices loudly proclaiming their own versions and visions of what science educators should do. There are so many different agendas that society demands that science education achieve. Among various issues of science education, my interests have focused on the notion of *scientific literacy for* *citizenship.* This involves forms of science education which have been trying to respond to the rapid changes in modern society.

With this focus, Chapter 2 will examine current discourses around scientific literacy, explaining the goals, interpretations, approaches, and critiques discussed in the science education literature. Based on a discursive reading of these various and sometimes incompatible or even incommensurable discourses, the chapter will open up a discussion about how we might understand and approach the notion of scientific literacy differently in today's science classroom.

# II

## SCIENTIFIC LITERACY & ISSUES OF S-T-S-E (Science-Technology-Society-the Environment)

Scientific literacy has been presented as a goal of science education that will support more balanced and effective science curriculum and science teaching for decades. To understand current discourses around scientific literacy, this section examines the ways in which scientific literacy has been developed and discussed among science educators and the issues and dilemmas science teachers have encountered in terms of its application (Chapter 2). Exploring basic issues of science, technology, society and the environment, this section continues to question the role of human agency in the discourse of modern science and technology as a means to discuss possible ways of cultivating scientific literacy for the 21st century (Chapter 3).

# CHAPTER 2

## THE DISCURSIVE MEANINGS OF SCIENTIFIC LITERACY AND SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT (STSE) CURRICULUM

### Introduction

To respond to the changes of modern society, largely led by technological change, science education communities have developed the notion of 'scientific literacy'. Consistent with my concerns and interests throughout this research journey, this chapter explores the ways in which efforts have been made to achieve the goals and ideals of scientific literacy.

By employing multilayered interpretations and various approaches to the construct of 'scientific literacy', this chapter reflects my contemplations on the conventional problems of scientific literacy, exploring areas in which the problems of unsatisfactory goals and strategies emerge, tentatively suggesting some ways in which we might strive to alleviate the existing barriers to cultivating the goals of scientific literacy in modern science classrooms.

## The repertoire of scientific literacy

### *Historical review*

The term 'scientific literacy' has been used to describe a set of goals for science education since it was coined in the 1950s in response to the perceived need for scientific and technological power as well as improved public understanding of science (DeBoer, 2000; Roberts, 1983). When scientific literacy was mentioned by Paul DeHart Hurd[4] in the Rockefeller Report in 1958, the term was used to represent a broad and general understanding of science and of the rapidly developing scientific and technological enterprise in modern society whether one was to become a scientist or not (DeBoer, 2000). It was concerned about our life efficiency and everyday ability to cope with socioscientific changes.

Despite this initial interest, after the Sputnik shock, in a broadly defined public understanding of science advocates of 'scientific literacy' in the 1960s became more keenly interested in the strategic roles of scientific knowledge in providing an adequate

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[4] Paul DeHart Hurd (1905-2001) is one of the most progressive educators whose career is devoted to ensuring the meanings, roles, and practices of scientific literacy in science curriculum and instruction for more than half century. He explained that science education needs to take into account connections between students' learning and their lifeworld, i.e., science as lived curriculum. He also emphasized science education reforms need to incorporate complex and rapid changes of science and technology in modern society in order to help students become informed citizens in coming era.

supply of technically trained scientists, mathematicians, and engineers for international economic competitiveness (DeBoer, 2000, Blades, 1995, 1997). Science education started focusing on the instrumental value of the discipline for economic and military enterprises and the gaps between scientific knowledge and everyday application became more problematic (DeBoer, 2000; Hodson; 2003; Hurd, 1998).

Science educators in the 1970s and early 1980s became concerned about these gaps and started to emphasize the important role of social contexts in science education. Science educators looked into students' knowledge and appreciation of science as possessing personal, social, and cultural dimensions that have the potential to connect students to their science learning and make it meaningful within their everyday contexts (DeBoer, 2000). The discussion of the notion of scientific literacy has continued with the concept of 'science literacy for all' in the 1990s and of 'scientific literacy for citizenship' in more recent times (Hodson, 2003). On the basis of this brief historical overview, I will now explore the (discursive) definitions and dilemmas of, and the approaches to, scientific literacy in the contemporary discourse of science education.

*The challenges of defining scientific literacy*

Due to the various movements using the notion of scientific literacy, sometimes with competing or even incompatible goals and imperatives, it is challenging to define what scientific literacy means and what an education for scientific literacy therefore needs to include and accomplish. Among various understandings of scientific literacy, it has generally been understood as the ability to 'understand' and 'do' science with creativity, practicality, and access to scientific knowledge in terms of both professional workforces and responsible citizens (Aikenhead, 1994; Driver et al., 1996; Galbraith et al., 1997; Hodson, 2003; Hurd, 1998; Kolstø, 2000, 2001; Norris & Philips, 2003; Pedretti, 2004; Roth & Desautels, 2004; Yager, 2000; Yore et al., 2003; Zimmerman et al, 1998, 2001). Balancing the two dimensions, however - one professional and the other civic - has been an ongoing dilemma in the history scientific literacy, raising political questions about 'scientific literacy for whom?' and about what level of practice and accessibility we aim for. For instance, is the primary goal of science education accessibility for citizens' understanding of science news articles or the preparation of candidates for professional science careers?

This conflict between professional career development and public understanding of science can be traced back to the claim made by Harvard Committee in 1945. The committee stated that "general education is used to indicate that part of a student's whole education which looks first of all to his/her life as a responsible human being and citizen; while the term special education indicates that part which looks to the student's competence in some occupation" (as quoted in Bybee, 1997, p. 73). Since both dimensions are potentially critical for students' lives as well as for society more broadly, it is not a simple task to consolidate the two different streams of scientific literacy in science curriculum and teaching (Klopfer, 1971 as quoted in Roberts, 1983). These divided perspectives have resulted in different agendas and in critiques and controversies between science groups and education sectors. Roger Bybee (1997) writes in *Achieving Scientific Literacy.*

> The tension between scientists and educators over the appropriate emphasis and content of science education is ongoing. Scientists, whose views have been shaped by their professional education and orientation, emphasize science content, often disregarding the educator's perspective. Conversely, educators, also influenced by their professional experiences, tend to overemphasize educational issues at the expense of science content. (p. 72)

The dilemma of the vocational and general purposes of science education encounters complex challenges in educational, sociocultural, and political relationships. As the roles of science and technology have been escalated by rapid changes in contemporary society, science education has been required to keep up with, or even expected to lead, social and political changes. Let us consider the following statement by George DeBoer (2000):

> The emphasis on disciplinary knowledge, separated from its everyday applications and intended to meet a perceived national need, marked a significant shift in science education in the post-war years. The broad study of science as cultural force in preparation for informed and intelligent participation in a democratic society lost ground in the 1950s and 1960s to more sharply stated and more immediately practical aims. (p. 588)

The tendency toward a model of science education focused more on scientific knowledge for professional and national purposes evoked concerns about pedagogical questions among science educators. The educators started questioning who the learners were in the classroom and whose scientific literacy we were concerned about. In accordance with these concerns, science educators came to challenge the notion of 'scientific literacy' with an increased emphasis on the personal and social contexts of science as a way to help the majority of students learn and understand science in everyday contexts.

*Scientific literacy for all*

Rosalind Driver et al. (1996) argue that the problem remains where science educators try to achieve both sets of goals - aiming for scientific literacy as career preparation and as general access to scientific knowledge in our communities - within the same science curricula. Both of these emphases have important roles in life and society and should not be ignored in science teaching, yet science education has put a strong emphasis on content-based knowledge and demands from the science professions to seek students' acquisition of 'correct' scientific vocabularies, concepts, and skills. This has occurred at the expense of considering students' lifeworld knowledge and developing public capacity for understanding and participation in science contexts. Driver et al. (1996) also state that "if science is a core subject for *all* pupils, the proportion who will use science for career purposes is likely to be relatively small. [Therefore,] the aim to improve scientific literacy is to increase public understanding of science" (p. 9). Therefore, it is appropriate for us to question the ways in which we consider the majority of students and their science and life in our teaching, i.e., the ways in which we enact *science for all.*

Enhancing general public understanding of science is a goal of science education that many science educators feel has been undervalued. Genuine interest and a sense of wonder about science are also seen as valid and important goals in relation to scientific knowledge. In vocation-oriented science teaching, the majority of students who will not enter scientific fields tend to get discouraged and disconnected from science (Driver et al., 1996). In spite of the goal of scientific literacy for all, current content-focused curricula are still delivered to the majority of students in science classrooms, and are seen as not serving them well. A predominant public reaction to discussion of science is "Oh, I'm not smart enough for science, I never did well in it at school".

Traditional ways of teaching science that focus on memorization, abstract content, strictly formulated lab reports, and score-based exams have led children to think that science is one of the more difficult and unpleasant school subjects. Students often lose their interest and enthusiasm and shun science classrooms. My students in my earlier classroom teaching often said, *"science is too difficult," "I wish I didn't have to learn this,"* or *"it is not for me."*

During my research with Korean 6th graders in 2003, I also had a chance to converse with students about their science learning experiences in casual occasions. During our conversations, some students said that *"science about the natural world is* *not boring but the science that we learn in school is not the same science out there"* and *"what we learn is not the science in everyday lives or in real life."* Test-oriented science education has created an assumption among some students that test scores prove their intelligence in relation to doing science. In their understandings, the score decides their eligibility to gain access to science. This has resulted in demarcations among students with and without access to science. Students 'without' science do not have much motivation or reasons to learn science. Some students expressed that they were not 'smart enough' to do science. A student said, *"If you are doing well in science, that means that you are smart."* Students feel frustrated and lose their confidence and interest in science. They feel neither engaged nor invited. They are uninterested and bored.

I wonder about their absent presence in the science classroom. I also wonder what the consequences of students' loss of self-confidence and related resistance or indifference toward science would be in their present and future relationships to science in social contexts. Their minds – distant from science - might develop inert, passive, or biased attitudes toward issues around science and technology. These notions are on-going concerns. I question, however, in what ways science curriculum reforms have been taking into account the importance of finding ways to invite students' dispersed bodies and minds into our science classrooms.

*Scientific literacy for citizenship*

In the discussion on scientific literacy for all, Driver et al. (1996) point out that *scientists are citizens too,* which emphasizes people's responsible and participatory actions in their labs as well as in public. Presumably, those with science expertise carry more responsibility than the general public in terms of their influence on the rest of society and that added responsibility creates ethical dilemmas of knowledge and practice for scientists (Fleming, 1989). The public also needs to realize the collective role of the empowerment of scientific literacy in the network of socio-scientific and technological discourses. There should be no distinction between the special and general purposes of science education when it comes to the socio-civic responsibilities of scientific literacy. In this respect, 'scientific literacy for all' leads us to take into consideration our responsible participation with scientific knowledge as citizens.

At the current time, with an increasing number of social issues that arise from the current activities of science and technology, the role of human agency in the context of science and technology has been emphasized. Accordingly, the goal of scientific literacy has been reexamined in the light of citizenship in socioscientific and technological enterprises and emphasized our responsible and active participation in modern global society (DeBoer, 2000; Hand et al., 1999; Hurd, 2002; Kolstø, 2001). Therefore, scientific literacy requires our awareness of the sociopolitical, ethical, and ideological values of science beyond the mere acquisition of scientific knowledge. Derek Hodson (2003) suggests that:

> Perhaps life in the 21st century will demand higher levels of scientific literacy than were previously required of citizens. Perhaps not. What is clear is that ordinary citizens will increasingly be asked to make judgments about matters underpinned by science knowledge or technological capability, but overlaid with much wider considerations. (p. 650)

Hodson claims that people without a basic understanding of the impact of science and technology upon the physical and sociopolitical environment will feel disempowered and vulnerable in attempting to exercise their rights within a democratic, technologically dependent society. Emphasis on the social contexts of scientific literacy suggests that science educators need to understand science teaching in relation to the practicality, relevance, and responsibility of knowledge for students' lives and society. In this regard, school science cannot be taught separately from today's world.

*The composition of scientific literacy*

In response to the role of science education in contemporary society, Robert Yager (2000), a science educator and researcher has particularly focused on the areas of scientific literacy, Science-Technology-Society (STS) curriculum, creativity in science learning, and students' attitudes toward science. He explains scientific literacy and STS education can be internalized and implicated in lifeworld situations through engaging students' subjective understandings in science learning. In his work, *A Vision For What Science Education Should Be Like For the First 25 Years Of A New Millennium,* Yager (2000) stresses the importance of new perspectives and approaches of scientific literacy, summing up the characteristics of scientific literacy – knowledge, skills, and attitudes – currently being discussed among science educators (see Table 2-1). He emphasizes the harmony of scientific knowledge and the lifeworld by stressing the significance of life experiences, a balance between epistemic knowing and emotive attitudes, and exploration of the creative implications of scientific literacy in world contexts. To achieve scientific literacy as life knowledge, he acknowledges the necessity of the involvement of human subjectivity. The question of subjectivity is an important notification to my understanding since scientific literacy for citizenship requires the creative and motivated involvement of human agency and this cannot be carried out without our subjective relationships to the issues which need our active participation.

Table 2-1. Components of scientific literacy

| Domains | Components |
|---|---|
| ***Concept*** (Knowing and understanding) | our *current* understandings of facts, concepts, laws, principles, hypotheses and theories being used by scientists around natural universe |
| ***Process*** (Exploring and discovering) | Scientific endeavors such as observing, describing, classifying, communicating, inferring, and hypothesizing interpreting and constructing |
| ***Creativity*** (Imagining and creating) | visualizing –producing mental images; combining objects and ideas in new or alternate ways |
| ***Affective-ness*** (Feeling and valuing) | developing positive attitudes toward science; developing positive attitudes toward oneself (an "I can do it" attitude); exploring emotions and sensitivity, respect; expressing personal feelings in a constructive way |
| ***Application and connections*** (Using and applying) | Applying learned science concepts, skills and process to everyday technological problems; understanding and evaluating mass media reports of science; making decisions related to personal, social, and environmental issues, based on scientific knowledge rather than on hearsay or emotions |
| ***World view*** (Viewing science and its history as human enterprise) | Considering the motivation of scientists and technologists; investigating how science and technology have advanced over the ages; understanding the relationships of science and technology in the society throughout the history |

(Source: Yager, R. (2000). A vision for what science education should be like for the first 25 years of a new millennium. *School Science & Mathematics, 100*(6), 327-342)

Yager's interpretation of global contexts of scientific literacy expands the notion of 'scientific literacy for citizenship' to 'scientific literacy for global citizenship'. Given that the social problems of science and technology are not only local but also global, scientific literacy needs to support our collective understanding and participation in a world-wide context, that is, global scientific literacy (Mayer & Tokuyama, 2002). Yager suggests that examining the history of science and technology would be helpful as a means to understand our present and future relations to science and technology. Such historical study also helps us to understand how we might collaboratively work through the global networks of modern science and technology to illuminate the goal of scientific literacy for global citizenship.

Strategic suggestions: How to approach scientific literacy

To enhance scientific literacy with one's own life contexts and social relations, there have been several suggestions put forward by science educators. Some are strategic and tactical suggestions and some are more intrinsic and epistemological approaches. All are worthy of our attention to cultivate the effectiveness of science teaching. Among them, the suggestions arising from the Science-Technology-Society-

Environment (STSE) curriculum movement is the main thread weaving the various approaches together to support moves toward 'scientific knowledge for participatory citizenship'.

*Science-Technology-Society-Environment (STSE) curriculum*

Adding the dimension of Science-Technology-Society-Environment (STSE) to science curricula has been proposed in Korea as well as in North America as a way to cultivate the connections of scientific knowledge to life situations. STSE education addresses multidimensional – interpersonal, social, economic, political, and global - issues related to science and technology. It engages controversial and ethical dilemmas of science and technology in our society and environment. As an example, in STSE approach, the topic of constructing dams not only investigates scientific and technological knowledge - kinetic energy, electricity, gravity, durability and compressibility of materials, and so forth – but it also explores the conflict between social and economic values and the destruction of natural habitats caused by dam construction. In genetic engineering, issues of DNA, heredity, stem cell research, and genetically modified organisms, based around human needs and social norms are the issues that are considered in our decision-making (Sadler & Zeidler, 2004). Engaging with the complexity of those issues helps students to develop critical thinking and responsible decision-making process.

The framework of STSE curriculum strives to accomplish the objective of scientific literacy for citizenship. Many science educators stress the importance of STSE education in helping students to develop the critical thinking and decision-making skills that will allow them to become responsible citizens in a democratic society (Aikenhead, 1994; Bingle & Gaskell, 1994; DeBoer, 2000; Hand, et al., 1999; Hodson, 2003; Hurd; 2002; Kirkham, 1989; Kolstø, 2001; Lawrence, et al., 2001; Martin & Brouwer, 1991; Patrick & Remy, 1985; Rubba & Wiesenmayer, 1991; Roth & Barton, 2004; Solomon, 1993; Zeidler et al., 2005 ). Through understanding the polemical and ethical dimensions of STSE issues, we learn how critical thinking is important to making mindful decisions and taking action over the issues. In STSE curriculum, science is neither value-free nor independent from human enterprises when it comes to human relationships to STSE in our lifeworlds.

In my work, STSE does not mean 'relationships only between humans around STSE', nor does it mean 'relationships with STSE'. It means 'relationships between and among science, technology, society and the environment, particularly but not only in the context of science education'. In modern technological society, understanding the complex relationships of STSE and the role of human agency in/to the relationships is crucial for us as citizens to become more informed decision makers and action takers in the context of STSE.

*Science as lived curriculum*

The emphasis on STSE relations leads us to look into our science teaching in relation to students' lived stories. When students' scientific knowledge is expected to be practiced in society, we also need to know how students experience science in their everyday lives in order to shape our teaching to enhance the connections between knowledge and life world. Hurd (1998, 2002) emphasizes that the current curricula, however, are still very disconnected from children's life experiences and not effective and reflective enough to address rapid socio-civic changes in modern society. Through inviting, unfolding, and dialoging with students' experiences and perceptions on everyday science and technology, we attempt to approach scientific literacy as embodied and lived knowledge. Hurd suggests that we need to embrace our human being-ness in the scientific world, teaching a lived science curriculum.

> What is sought is a lived curriculum in which the major instructional standards and intellectual skills are those to enable individuals to cope with changes in science/technology, society, and the dimensions of human welfare. Most science curricula found in schools today are descriptive, focused on the laws, theories, and concepts of presumably discrete disciplines. In contrast, the lived curriculum is where students have a feeling that they are involved in their own development and recognize that they can use what they learn. (Hurd, 1998, p. 411)

He mentions that for centuries, the improvement of science curricula has been viewed as a matter of simple updates to the subject matter of traditional disciplines.

> A failure to recognize changes in either the practice of science or shifts in our culture continues... Education in the sciences takes on new dimensions with the changing image of science/technology, a rapidly changing culture, and a knowledge-intensive era. (p. 411)

This comment raises a question for me: What needs to be considered to overcome the habitual routine of science curriculum reform? What are we fundamentally missing as we attempt to approach STSE education differently?

*Contextualized science stories*

When STSE stories are told in classrooms, the strategies need to be tactful (van Manen, 1991). Douglas Roberts (1995) suggests his notion of the 'companion meanings' of science stories as an approach to the incorporation of life contexts in science learning. A science story accompanies 'companion meanings' relating to its social and human contexts and to notions about the nature of science and knowledge as well as the scientific meanings of concepts. For example, by integrating topics of chemistry and physics around the themes of nuclear energy, science stories can be carefully constructed to provide students with conceptual information about physical and chemical changes, atomic structures, and energy creation, as well as contextual information about the usage of energy and its impact on the environment and human life. Consequently, Science-Technology-Society-the Environment companion stories can be sensibly developed to address controversial issues around major concepts of the topic, for example the consequences of nuclear wastes and debates about nuclear armaments. Roberts insists that companion stories need to be told in a tactful manner:

> Companion stories must be selected and conceptualized with as much care as science stories, with attention to sociopolitical factors of the curriculum struggles as well as logical factors of teachability and coherence. (Roberts, 1995, p. 115)

Companion stories are contextual and situational, and thereby bring forth the relevance of science learning to students' personal lives and citizenry. He argues, however, that science stories often appear only in the corner box in the textbooks, which shows a perpetual tokenism in attitudes toward companion meanings.

*Linguistic abilities for scientific literacy*

A majority of students will not have many opportunities to obtain formal science learning after graduating from high school. The only methods by which they encounter science and technology are through mass media; news articles, magazines, science exhibitions and other public channels. What do graduates of school science education programs need to know and be able to do in order to understand and evaluate scientific information in those texts and contexts?

A side strand of the broader discussion of scientific literacy has seen scientific literacy as part of grand scheme of literacy more generally; reading and writing skills in all disciplines including mathematics and science. In order to understand and participate in scientific debates in the public dimensions, Philips and Norris (1994) and Zimmerman et al. (2003) note that scientific literacy needs to go beyond what's in the textbooks so that students can read and evaluate cutting-edge or frontier science in media reports on scientific journals, magazines, and newspapers.

Norris and Philips (2003) argue that the fundamental sense of scientific literacy requires reading and writing skills since western science heavily depends on written texts. To promote students' scientific literacy in terms of the interpretation and analysis of science texts in public domains, they emphasize the need for fundamental literacy skills in science education settings. Analyzing, interpreting, and discussing articles in newspapers, magazines and journals in science classrooms has been proposed as a way of enhancing students' abilities to understand contemporary science and its actions.

Table 2-2 is a summary of the forms of scientific literacy discussed through this chapter.

Table 2-2. The current discourses of scientific literacy

***Emphasis of scientific literacy*** ***...What does scientific literacy aim for?***

***Scientific literacy for all***

(Driver et al., 1996; Galbraith et al., 1997 ; Roberts, 1983)

Science education as preparation for the professions or as general public understanding of science?

— Recognition of the majority of students who will not work in professional science fields

— Recognition of the disconnection between school science and everyday science

Table 2-2 Contd.

***Scientific literacy for citizenship***

(Aikenhead, 1994; Hodson, 2003; Hurd, 1998, 2002; Kolstø, 2000, 2001; Patrick & Remy, 1985; Yager, 2000; Zeidler et al., 2002, and many others)

Scientific literacy as national competency or socio-civic knowledge?

— Complex issues around STSE and current science curriculum

— Decision-making and taking action as scientifically literate citizens in individual and public domains

***Approaches to scientific literacy*** *... How can we approach scientific literacy?*

***Interrelationships of STSE issues***

STSE curriculum as civic scientific literacy for citizenship

(Aikenhead, 1994; Hodson, 2003; Hurd, 1998, 2002; Kolstø, 2001; Pedrettii, 2003; Solomon, 1993; Yager, 2000; Zeidler et al., 2002, and many others)

***Learning with lived experiences***

Context-bound science learning:

Science as lived curriculum & Science stories

(Aikenhead, 1994; Hurd, 1998; Roberts, 1995; Yager, 2000)

***Reading/understanding media reports on science***

As communicative skills of literacy: reading and writing abilities to understand and participate in public scientific discourses

(Hand et al., 2003; Norris & Philips, 2003; Yore et al., 2003; Zimmerman et al., 1998, 2001)

## The problematic issues of scientific literacy

Despite the fact that there have been great efforts to discuss scientific literacy in terms of students' responsible participation in decision-making and of the sociocultural dimensions of scientific knowledge, there has not been much progress and few changes have been observed in classroom teaching and students' understanding (Hurd, 2002; Pedretti, 2004; Roberts, 1995; Shamos, 1995). For example, STSE curricula have been suggested as an approach to teaching science in ways that recognize the associated socioscientific issues for more than a decade. However, STSE practice in classrooms has remained insufficient, and STSE dimensions are often taken as an 'add-on' or 'peripheral curriculum' (Pedretti, 2004; Roberts, 1995).

To understand the lack of progress and change in school curricula and pedagogy in relation to scientific literacy and STSE education, it is critical to question where the difficulties surrounding scientific literacy lie and in what way they make the implementation of scientific literacy complex and challenging in classroom practice.

Firstly, a problem lies in the broadness and crowdedness of the sets of skills encompassed under the term 'scientific literacy'. It is hard for us to understand what scientific literacy means operationally and how to approach it where there is no solid single definition of scientific literacy nor one that seems to include consideration of STSE issues and students' lifeworld contexts. There seems only science 'content' knowledge and skills construed as scientific literacy in science curricula. Some would go so far as to suggest that the meaning of 'scientific literacy' has become too big and abstract to achieve its goals or even to understand what it is (Shamos, 1995). Scientific literacy tries to serve too many different demands and societal agendas (Driver et al., 1996). Some critics argue that we cannot have a single understanding of scientific literacy. Having one would be only an illusion, says DeBoer (2000). He argues that each of us needs to comprehend how to creatively and mindfully understand scientific literacy among its multidimensional approaches. Under these circumstances, science teachers' attentive and critical decision-making processes are critical in terms of the directions and strategies they choose to approach scientific literacy in their practice.

While scientific concepts and skills can explicitly be presented as scientific literacy, however, their implicit dimensions - i.e., the attitudes and values of science - are not easily recognized and practiced. For example, in terms of scientific literacy for citizenship, we teach explicit scientific knowledge and we also aim implicitly to develop students' capacity for acting responsibly as citizens. This raises the question: "is it possible to foster students' appreciation of, and critical minds toward, science while teaching the requisite content knowledge in the context of explicit scientific literacy?" Science teachers encounter the concerns of both dimensions of scientific literacy – science education as professional preparation and science education for (global) citizenship – in the context of limited class conditions.

Within these concerns, science teachers strive to make their decisions, oscillating back and forth between the implicit and explicit goals of scientific literacy. In order to help science teachers with the difficulties of decision making, the provision of concrete and achievable taxonomies of concepts and skills in science curriculum can be helpful. Strategic materials, tools, or techniques will also alleviate their concerns. Those curricular and pedagogical supports, however, need to go beyond mechanical or temporal adaptations, challenging science educators to question how they interpret the meanings and roles of scientific literacy and bring them forth through our teaching in contemporary society.

Secondly, there are on-going political moves in standardized science curricula which put scientific literacy for citizenship and STSE education at risk (Blades, 1997; DeBore, 2000; Hodson, 2003). The social and political agenda to compete in international relations – global economy, technological innovations, and military forces influences science curriculum development to focus on students' conceptual knowledge and skills and consequently have an effect on teachers' classroom practice. In response to these demands for greater standardization and accountability, science curricula tend to become more content- and test-oriented and STSE dimensions of scientific knowledge to be undervalued and left behind in the competitiveness of local and global society and in a particular ideologically defined set of proposed 'solutions' to that competitiveness, based in 'accountability' and surveillance. This tendency pressures teachers and their practice in the pedagogical dilemmas as they are demanded to make hard choices among children, curriculum, and social demands.

Lastly, the central problem lies in the epistemology of science education, which leads our conceptions of 'scientific literacy' to reflect a disconnection between objective scientific knowledge and subjective human worlds. In western science, objectivism[5] has separated scientific knowledge from human subjectivity for a long time. Paired with the perceived certainty of scientific knowledge, modern technology has also been seen as promising infinite development of human civilization. Objectivist views of science and technology suppress consideration of subjectivity. With an objectivist understanding of science in our minds, our science teaching also focuses on

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[5] Objectivism views scientific knowledge as pure objective descriptions of natural phenomena. Knowledge is seen as in some sense external to the mind (or at least as externally testable and verifiable), therefore, under objectivist assumptions, subjective ways of knowing - feelings, emotion, intuition - should not be included in the development of scientific knowledge.

the objectivity of scientific knowledge with limited recognition of the subjective, human, social or cultural aspects of knowledge. Scientific literacy continues to be interpreted in terms of objective content knowledge and skills. Where do these 'separate knower' (Belenky et al., 1986) views of science come from, and why are they perpetuated in our science classrooms? What would be possible ways of understanding – and perhaps beginning to challenge - this persistent notion of objectivism in our science teaching? To understand this dilemma of scientific literacy, we might need to challenge the notion of 'scientific literacy' with different views; not so much searching for new definitions, compositions, or strategies, but questioning our epistemological assumptions about science and scientific knowledge.

With this question in mind, I attempt to discuss basic issues of modern science, technology, and society in Chapter 3 in order to challenge assumptions about the objectivity and absolutism of science and explore the importance of human relationships to scientific knowledge and action.

# CHAPTER 3

## PHILOSOPHICAL PERSPECTIVES ON SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT

### Introduction

In order to support a deeper understanding of the difficulties of cultivating a view of scientific literacy as life knowledge that is connected to human and citizenship dimensions, this chapter explores some of the basic issues of science and technology in modern society. Examining widespread views on the nature and influence of science and technology, I explore the ways in which these common views of science and technology can be examined in order to cope with the difficulties of scientific literacy in our teaching practice. Where scientific knowledge privileges empirical and analytical reasoning in quest of certainty and objectivity, human subjectivity comes to be viewed as deficient and uncertain, and is therefore often seen as something that needs to be avoided in science. This notion of objectivity and certainty is entrenched in modernist ways of understanding the world around us. Science teaching, despite efforts since the 1960s, barely addresses the connections between scientific knowledge and human dimensions. This tendency perpetuates the separation of the various dimensions of scientific literacy (discussed in Chapter 2) in science classrooms.

To better understand the issues of scientific literacy and life connection, this chapter also explores the meaning of technology. In modern society, science has become a complex set of notions about knowledge and its implications which tightly connect the human, social, and cultural dimensions in scientific enterprises. (I am making the argument that science education is currently failing to adequately reflect this complexity.) Within this complex understanding of science, technology becomes a significant part of contemporary scientific literacy, in that it requires modern human beings to understand the complex interactions of science with technology as well as to have a good understanding of the nature of both science and technology and the differences between them. In the later part of the chapter, the complex issues of science and technology are examined in the scheme of social relationships in order to stress the necessity of responsible relationships to scientific literacy in modern society.

Science and scientific knowledge

Etymologically, the word 'science' stems from the Latin *scientia,* knowledge, from the verb *scire* to know. Based on empirical methods, the repertoire of science has been regarded as a firm, objective and value-free zone of truthful knowledge about the world (Sismondo, 2004).

Recent philosophies of science have challenged our understanding of science as absolute truth by acknowledging the uncertainty and relativity of scientific knowledge. Philosophers of science such as Karl Popper (1959, 1965) and Thomas Kuhn (1970/1980) have suggested that science includes human agency – sociocultural and scientific communities - in its knowledge development and justification processes. Even though their theories and approaches are different from one another, Popper and Kuhn are agreed on the uncertainty of scientific knowledge, in opposition to traditional positivists[6] views of scientific truth. In this section, I focus particularly on the ideas of Karl Popper and Thomas Kuhn in order to question the absolutism of scientific knowledge.

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[6] Positivism was first coined by Auguste Comte (1798-1857) and later taken on by various scientists, social scientists, and philosophers as a way of understanding the phenomena of human beings and the universe. Positivism emphasizes that knowledge is from empirical and analytical scientific methods based on reason and logic. Knowledge is observable, measurable, and objective from positivistic perspectives. Therefore, scientific knowledge is seen as certainty and affirmation of the truth of the world.

*Karl Popper: The essential uncertainty of science*

Karl Popper (1959, 1965), in attempting to solve (or at least to sidestep) the 'Problem of Induction' in philosophy of science, explains theory-testing and falsification as keys to scientific progress. When evidence is found that a theory/hypothesis is wrong, the existing theory/hypothesis has been refuted and a new one has to be developed. He explains that existing theories are not necessarily true but are simply those that have not been refuted yet, and claims that the openness of theories to refutation and falsification is what make them scientific. With this openness to refutation at every step, scientific knowledge is considered to be neither absolute nor ultimate. Popper also makes a distinction between truth and certainty.

> There are uncertain truths...but there is no uncertain certainty. Since we can never know anything for sure, it is simply not worth searching for certainty; but it is well worth searching for truth; and we do this chiefly by searching for mistakes, so that we can correct them. Science, scientific knowledge, is therefore always hypothetical: it is *conjectural knowledge*. And the method of science is the *critical method*: the search for and the elimination of errors in the service of truth. (1984/1992, p. 4, Italics original)

What needs to be considered is that the notions 'scientific truth' and 'certainty' are used interchangeably in the public but are fundamentally different according to Popper. In his view, there exists (conjectural, falsifiable) truth that needs to be sought.

Through consistent trials and errors, we reach better explanations of truth and scientific knowledge changes and develops. In the process of seeking truth, scientific knowledge is uncertain and unfixed.

In this respect, Popper underscores the uncertainty of scientific knowledge by stating that "science does not rest upon rock-bottom certainty. The bold structure of its theories rises, as it were, above a swamp...we simply stop when we are satisfied that they are firm enough to carry the structure, at least for the time being" (Popper, 1959, p. 111). Scientific knowledge is uncertain because we human beings consistently endeavor to seek truth through enhancing our scientific explanations – including refuting and replacing current explanations.

*Thomas Kuhn: Paradigmatic challenge to 'normal science'*

The spatial and temporal situatedness of scientific knowledge is well explained in Kuhn's (1970/1980) notion of 'paradigm'. In his book, *The Structure of Scientific Knowledge,* Thomas Kuhn (1970/1980) introduces the concepts of 'paradigm shift' and of 'normal science as puzzle solving' to explain the revolutionary processes of scientific knowledge development. He describes ways in which the scientific community establishes a 'paradigm', which is taken as an accepted model or pattern of theories and laws. Kuhn uses the word 'paradigm' in a number of ways, including to describe a particular experiment or finding from the new set of theories, but the most important sense of the term is to describe a linked set of theories, methods, and approaches to inquiry.

The validity of scientific knowledge claims can be ascertained only within certain scientific communities which share similar professional assumptions and standards for judgment in the accepted paradigm. Through scientific hypotheses and experimentation, puzzles are solved, but the solutions are accepted or rejected within the existing paradigm under its standards. Thereby, scientific knowledge normally develops within the paradigmatic boundaries. Kuhn terms this process as a "normal science" (Kuhn, 1970/1980).

Because of the boundaries and framework of normal science, the realm of truth in scientific knowledge can be interpreted differently in a different paradigm as seen in the examples of Newtonian and Einsteinian theories of dynamics. Kuhn explains, "paradigms *could* determine normal science without the intervention of discoverable rules...Normal science can proceed without rules only so long as the relevant scientific community accepts without question the particular problem-solutions already achieved" (ibid., pp. 46-47, Italics original).

When the existing paradigm cannot explain and solve puzzles and abnormalies emerging from discoveries (The movement of Mercury), the existing paradigm (Newtonian physics) is replaced by a new paradigm (Theory of Relativity) which can explain the phenomena, which Kuhn terms as a scientific revolution, that is, a 'paradigm shift'. Kuhn explains that "what occurred was neither a decline nor a raising of standards, but simply a change demanded by the adoption of a new paradigm" (ibid., p. 107). Thus, according to Kuhn, scientific knowledge cannot be cumulative but old findings will either be replaced or have new meanings under the new paradigm. Scientific progress, therefore, can be seen as revolutionary rather than evolutionary or foundational/cumulative.

Paradigm shift is driven by communal and social forces. In other words, the construction and contextualization of scientific knowledge involve the knower, and occur in the human realm of knowledge-making. The validity and accountability of knowledge is founded not in the claim that a constructed knowledge can explain all situated phenomena perfectly without exception, but on the basis that it is the most suitable and appropriate theory to explain the phenomena for that time being until it is replaced with a better explanatory theory.

*Understanding science as process vs. ready-made science*

Both Popper and Kuhn claim that scientific theories, rather than being treated as ultimate truth, are continually challenged, altered, and developed through scientific methods. In the process of scientific knowledge development, the involvement of human beings as knowers and actors is indispensable. This recognition raises questions about what we claim as scientific knowledge and how we test those claims to know. With the understandings of scientific knowledge and human practice stemming from the work of Popper, Kuhn and others, science has come to be understood as a process of human and social interactions with the natural world.

Introducing the notion of science-in-the-making as apposed to ready-made science, Bruno Latour (1987) sees scientific knowledge as a process not a product. In ready-made science, knowledge is certain, fixed, and unquestionable truth whereas in science-in-the-making, knowledge is open to challenges, contestable, and therefore, unfixed. The notion of 'science as a process' opens the possibilities of the uncertainty of scientific knowledge and the use of and creativity in science work and learning.

Without uncertainty, there would be no progress of scientific knowledge, says Popper. When our theories are seen as uncertain in relation to a phenomenon, we seek more certain and suitable explanations to understand the phenomenon, and thus, knowledge develops in the dynamics of uncertainty (Popper, 1959). Uncertainty is also a place where our understanding of scientific knowledge can recognize human agency and its visions. Instead of limiting our understanding of science to objectivism and reductionism, we might consider more open and creative dimensions of science education in order to embrace the possibilities of uncertainty and human participation in scientific knowledge development.

School science education, however, abides in the domain of Latour's (1987) ready-made science and students learn theories, laws, and formula as the truth of science (Bingle & Gaskell, 1994; Kostø, 2001; Shamos, 1995). In the epistemology of 'science as absolute truth', uncertainty is rejected as a pitfall. Recognizing the existence of human subjectivity puts the certainty of scientific knowledge and technological practice at risk. This generates resistance from objectivists and empiricists whose views on science are certain and objective to the notion of uncertainty in modernist perspectives on science. Some consider that any humanization or socialization of science could hinder the development of science, and in turn, the progress of societal conditions because when human subjectivity is involved in the discourse of science, its knowledge becomes uncertain and not objective (Sismondo, 2004). In this regard, there remain great challenges in acknowledging the possibilities of the uncertainty of scientific knowledge and the relationships of scientific development and humanity. I would argue that the benefits of recognizing the uncertainty in science, and including such views on social process of science in school science education. After all, such views are nearly half a century old in the philosophy of science.

Questioning the link between technology and science

*Technology with/out science*

Technology is normally regarded simply as applied science consisting of design, skills, technique, tools, and technical innovations (McGinn, 1991). Given that technologies such as brewing, construction and metallurgy were present in human history long before the arrival of anything that might plausibly be called modern science, it is not correct to assume that technology is completely dependent on science, nor is technology merely applied science or a subordinate structure of science. In modern society where science and technology are intermingled in complex ways, the presence of technology is not a simple dimension of science at all (Brower, 1992; Fleming, 1989; Franklin, 1992; Latour, 1999; McGinn, 1991).

To some extent, conversely, science can be considered to be applied technology, in the sense that it is impossible to project and carry out many scientific developments without technological bases and supports (Hurd, 1998). Sergio Sismondo (2004) argues that sometimes science depends on technology more than technology does on science. He points out the autonomy of technological practice, which has its own traditions and socialization. "For example, work on the history of aircraft suggests that aeronautical engineering is relatively divorced from science: engineers consult scientific results when they see a need to, but there is no sense in which their work is driven by science or in which it is the application of science" (p. 76). This view can be useful as a way to alleviate the dialectic tensions between conceptions of 'science as base or knowledge' and 'technology as practice or production'. From this perspective, technology can be taken not as merely the application of science but as a unique form of cognition and tradition with its own interactive relations to nature and human life. Technology in the modern world is more like an independent and self-organizing system that connects science and society into human practice (Franklin, 1992). Ursula

Franklin (1992) in her book of CBC Massey Lecture, *The Real World of Technology* explains technology as practice. She writes, "technology is a *system*. It entails far more than its individual material components. Technology involves organization, procedures, symbols, new worlds, equations, and, most of all, a mindset" (p. 12, italics original). Franklins' study of the history of technology introduces questions about the relationship we as modern human beings establish with technology and how we dwell in those relationships.

*Martin Heidegger: The question concerning technology*

Martin Heidegger (1954) moves beyond the question of how we know about technology to how we inquire into the way technology influences human relationships with the world, i.e., an understanding of the ontology of technology. According to Heidegger (1954), technology is not a mere means such as a tool or a technique. It is the realm of revelation of truth. The Greek word, *technē*, from which the English word technology is delivered, possesses the meanings of not only the "activities and skills of the craftsman [but also] the art of the mind... *Technē* belongs to bringing forth, to *poiēsis*; it is something poetic...It reveals whatever does not bring itself forth and does not yet lie here before us... [Therefore] technology comes to presence in the realm where revealing and unconcealment take place, there *alētheia*, truth, happens" (Heidegger, 1954, pp. 294-295).

To explain how technology is interrelated with human agency and the environment, Heidegger takes up Aristotle's 'four causes', which are foundational to western rationality and science: 1) the material cause – matter of a thing (e.g., silver), 2) the formal cause – pattern, model, or structure (e.g., a chalice), 3) the final cause – goal, purpose, function or potential (e.g., sacrificial vessel), and 4) the efficient cause – means or agency (e.g., a silversmith). He posits that in order to understand the instrumentality of technology, we need to understand its fundamental base, that is, causality. Questioning causality leads us to explore the ways in which human agency is positioned in the relationships of technology, truth, art, nature, life, and values. Heidegger emphasizes the dimension of the efficient cause.

> The silversmith considers carefully and gathers together the three aforementioned ways [material, formal and final causes] of being responsible and indebted. To consider carefully is… to bring forth into appearance. The silversmith is co-responsible as that from whence the sacred vessel's bringing-forth and subsistence take and retain their first departure. The three previously mentioned ways of being responsible owe thanks to the pondering of the silversmith for the "that" and the "how" of their coming into appearance and into play for the production of the sacrificial vessel. (pp. 291- 292)

A human agent carefully takes responsibility for the instrumentality of technology and respects his/her relationships to the world. The authorship and authenticity of the silversmith create and are created by the spirit of art, *poiēsis*, something poetic and truthful, according to Heidegger (1954). The situatedness of occasioning reveals the *poiēsis* of the 'thing[7]'. It brings forth the world in the situation at hand.

However, human agency is not always carefully and respectfully engaged in bringing forth the causality and instrumentality of technology. The unique position of human beings as 'being agents' in a nonreciprocal world puts us in the mode of ordering and destining as a way of revealing, that is, it drives technology forward to the world. The tendency to challenge, control, and master lurks in this bringing forth process. Human beings begin to regard nature as a cornucopia of calculable resources, forgetting the responsible arts of *poiēsis*.

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[7] Hans-Georg Gadamer (1983) takes the notion of *poiēsis* further into the realm of "practice." The *poiēsis* of technology focuses on 'making a thing', on final production, whereas practice in technology emphasizes 'doing a way' to make things happen. He insists that it is practice that involves human agency in technology. Thus, he puts emphasis on practice as a means to understanding the complex relationships between humanity and technology.

Heidegger points out that the very framework of 'challenging nature' and 'nature as standing-reserve' became the essence of modern technology. He phrases it as "*Ge-stell* [enframing]" (p. 301). Ironically, enframing ultimately puts human beings themselves into the mode of standing-reserve.

> As soon as what is unconcealed no longer concerns man even as object, but exclusively as standing-reserve, and man in the midst of objectlessness is nothing but the order of the standing-reserve, then...he comes to the point where he himself will have to be taken as standing-reserve. Meanwhile, man, precisely as the one so threatened, exalts himself to the posture of lord of the earth. In this way the illusion comes to prevail that everything man encounters exists only insofar as it is his construct. This illusion gives rise in turn to one final delusion: it seems as though man everywhere and always encounters only himself. (p. 308)

Because the technology no longer belongs to the maker and because its original purpose sometimes gets lost and the technology comes to be used for different ideas, it is difficult to examine, restrain, control, and understand the *poiēsis* of *technē* in technological processes over time. Especially in modern high-tech society, the origin of some technologies is impossible to chase down. It may be impossible to understand the causality of, say, a cell phone as may have been done with the work of a silversmith in earlier ages. This lost chain of causality in modern technology inevitably brings about conflicts with human life - not only functional and instrumental conflicts but also psychological entanglements in the society and culture (Barrett, 1978; McGinn, 1991; Mayor, 1999).

In the modern era, new feelings - about loss of control, the anxiety of obsolescence and the fragility of humanity - have been engendered within the incomprehensibility of the polymorphous complexity of contemporary technology[8], the presuppositions of the technical world, and the undesirable outcomes of modern science/technology (McGinn, 1991; Shiva, 1997). In this complex web of relationships with technology, where can we begin a dialogue to understand being and life in the modern technological era? Heidegger emphasizes the importance of poetic and responsible paths by introducing a poem by Hölderlin (p. 310).

> But where danger is, grows
> The saving power also.

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[8] Robert McGinn, (1991) introduces *polymorphism* as a characteristic of modern technology. He suggests that modern technology is composed of various aspects of techniques that are intertwined with complex social and technical systems, and thereby, the majority of people need external supports to gain access to the technologies. In this way, opportunities for access decrease and people are afraid of losing control over their technologies. McGinn argues that the rapid changes of cutting-edge technology and human loss of control/autonomy over mechanisms and specializations causes anxiety and leads to negligence toward responsible participation in technological enterprises.

And he closes his essay with this passage:

> The closer we come to the danger, the more brightly do the ways into the saving power begin to shine and the more questioning we become. For questioning is the piety of thought. (p. 317)

Where and how, then, can we begin questioning modern technology which consistently unfolds the complexity of its causality and instrumentality in front of us? And to what extent do we as human agents take part in the processes of technology in this modern world? To understand these questions, I will explore our participatory relationships to technology, highlighting Bruno Latour's (1996, 1999) notion of technology in the following section.

*Bruno Latour and Actor-Network Theory*

Bruno Latour (1999) acknowledges that we need receptive and active ways to understand our relationships to modern technology, given that human beings' technological engagements have never been separable, from the beginning of the history. Even though both Heidegger and Latour raise questions about how human agency is to be responsibly engaged in the discourse of technology, their approaches are very different. Whereas Heidegger draws our attention to the dangers of modern technology, Latour approaches it with more intimate approaches to understanding human-technology relationships.

For Latour, technology is an essential medium that makes our relationships to the world possible. Introducing Actor-Network Theory (ANT), Latour (1996) explains how technology and science interplay in a web of wholesome hybrid mediations, that is, a *network*. ANT is a study of the intermediate relations which actors - humans and nonhumans (artifacts, services, systems, texts, languages, etc.) - create in the network. Actors influence each other's micro systems and macro environments, collapsing the boundaries of nature and society, humans and nonhumans, and subjects and objects.

> For the analysis of socio-technological development, such a tool is the Actor-Network Theory. It examines how competences are distributed within heterogeneous networks composed of human and non-human actors. Actors and networks are mutually constitutive in the sense that a network shapes and defines the actors who align themselves into a network. (Stalder, 1997)

In Actor-Network Theory, humans and nonhumans are a collective, mutually interacting, shaping, and translating each other. Nonhuman actors (machines, automatons, devices) are also considered as active agents that participate in creating the dynamics of the networks.

Latour understands technology as a significant nonhuman agent in our social relationships, one which sometimes 'rules back' humans with its own agency. For example, a coin is a nonhuman actor but its agency actively creates various new situations in the human relationships in a society. Its system stays strong, firm, and even self-regulating. It hardly falls away from the whole network of society. To portray the collective network of modern technology, Latour (1999) writes in *Pandora's Hope*,

> Those who have tried to distinguish these two sorts of collective [human/nonhuman] by attributing "objectivity" and "efficiency" to modern technology and "humanity" to low-tech *poiesis* have been deeply mistaken. Objects and subjects are made simultaneously, and an increased number of subjects is directly related to the number of objects stirred – brewed – into the collective. The adjective modern does not describe an *increased distance* between society and technology or their alienation, but a deepened *intimacy*, a more intricate mesh, between the two. (p. 196, Italics original)

When we enter into the complex transactions and mediations of the collective, there is no distinctive separation between humans and nonhumans. This is the point at which we break the chasm of modernism as Latour describes.

Latour (1993) claims in his book, *We Have Never Been Modern,* that we have never lived in the world of two separate poles; human and nonhuman, society and nature and society and technology. It is our illusion that we have lived in the modern era: Latour's claim is that the separation of human and nonhuman has never actually existed. Of course, his network theory does not discard the separations that exist on our physical borders but rather it emphasizes that it is our perspective on our relationships with others, the natural world and technology (the constructed world) that is not and should not be separated. In the time and place in which we are living, humans and non-humans are interlocked to one another and become one network.

In the network, human agency and science/technology are mutually facilitated, integrated, and shaped in the space of co-existence and co-emergence of humans and nonhumans. Latour (1999) points out that science and technology need to be understood as processes in the socio-technical network. Without understanding these interrelationships, we create separation and perpetuate the illusion of an iconic realm of science and technology[9].

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[9] Latour (1999) explains that the key to the problem is that we have generated fetishes instead of factishes through the development of science and technology in our social relationships. This neologism, 'factishes' is a "combination of facts and fetishes and makes it obvious that the two have a common element of fabrication" (Latour, 1999, p. 306). He clarifies that non-humans in a collective need to be set in the realm of factishes, not fetishism. As long as we separate facts as reality or knowledge from fetishes as belief through the presuppositions of fabrication, there emerges a gap between the human and nonhuman pushing us away from 'collective thinking'. In the separated dimensions of facts and fetishes, science/technology and morality/humanity become incompatible and indifferent questions to each other. Latour proposes that we reestablish our relationships to science and technology as a significant actor of the network in the domain of factishes.

With respect to co-existence and co-emergence, ANT shares the idea of inter-actions and co-relationships between actor and network and human and its environments with neighboring theories such as Humberto Maturana and Francisco Varela's (1987) concept of autopoiesis and structural coupling and Fritjof Capra's (1996) ideas on systems thinking (Stalder, 1997).

*Now I am left with challenging questions about how I re-establish my understanding and action in relation to this nonhuman actor - technology - in my micro and macro worlds. How does technology shape our everyday actions in the world and vice versa? What historicity and presuppositions about technology do we hold in our social relationships? What relevance does this have to science teaching?*

Given Heidegger's suggestion that we attend to the causality and instrumentality of technology, it is meaningful to ask the more basic questions that are observed by everyday relations with technology. It re-minds us of our agency and desire in relation to technology. On the basis of those understandings, Latour's cross-disciplinary approach helps to understand some of the practicality, transactions, and plasticity that modern technology can also offer to human lives.

The saving power grows not only with a recognition of the danger but also with our intimacy with technology. Both Heidegger's and Latour's ideas deserve our attention and thorough questions about how we live with technology and how the environment re-contextualizes and reshapes our relationship to the world. One could choose to stand by either an anti- or pro-technological point of view, or hold both positions in a dialectical tension to reap their harmonic benefits. It is not a question of which position we take, but rather of how we are mindful and critical as we continue our relationships with technology and humanity in modern society. It is these relationships that need to be questioned.

## A network of science and technology in society

When we ponder the meaning of scientific literacy in modern society, the question leads into another level of the social, political, and economic dimensions, that is, globalization[10]. When it comes to the social and cultural aspects of science and

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[10] David Smith (2003) explains three aspects of globalization. Globalization One is the dominant form arising from the revival of radical liberalism, i.e., neoliberalism. Globalization Two is public reactions;

technology, scientific literacy cannot be limited to local situations in the age of globalization. A simple example would be climate change. The issue of climate change is not only a personal and local phenomenon but also involves a complex network of scientific, technological, economic, and political dimensions on the international scale. When the world is understood as one shared place, knowledge of and about science and technology becomes more social, political, and global. We locally and globally share the issues that are the focus of the STSE movement in science education, such as ecological crises, nuclear armaments, genetically modified food, and reproductive technologies. With the increasing concerns about STSE issues, it is vital to question how science and technology have been practiced in global society and how science teaching responds to those concerns in contemporary science classrooms.

*Understanding science and technology in the age of globalization*

Science and technology have been intimately related to social and political interests throughout history. For example, the marriage of ships, maps, accurate

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adaptation and resistance toward Globalization One. Globalization Three is a new form of global dialogues for sustainable human future, for example, the realization of today's children and mindful pedagogy in global time. In this section, I highlight the relationships of science, technology, and society particularly, in the notion of Globalization One.

timekeeping, compasses, and gunpowder played a significant role during the European colonial era (McGinn, 1991). After the end of the global trading empires (Dutch, Spanish, Portuguese, French and English) and progressive decolonization, science and technology became even more important to the infrastructure of postcolonial developments than before (Burbules & Torres, 2000; MacLeod, 2001; Roth & Barton, 2004). We need to clarify that it was not the scientific and technological revolution that initially led the world into the colonial era but the formulation of modernity, but it is fair to say that extensive imperial expansion of science and technology provided a basis for the knowledge culture and served imperialism in the ultimate cause of power dependency in the colonial era (Barton, 2001; Dussel, 1999; Shiva, 1997; Willinsky, 1998; Vanderburg, 2000).

In the postcolonial era, the high investment in military- and industry-based scientific and technological research and development (R & D) demonstrates and creates the even tighter integration of science and technology with sociopolitical and economic systems (Gray, 1999; Mayor, 1999; Petrella, 1992; Rees, 2002; Wilson, 2002).

> Science became a key aspect of a global intelligence system, which served best the interests of those best placed to receive its data. Science became, in turn, both a colonizing ideology and an agency of colonial self-identity. For a colony, the pursuit of science became a license for membership on the community of nations. Today, the processes by which science served colonial expansion are fundamental to understanding science in the modern world. (MacLeod, 2001, pp. 10-11)

There is a strong likelihood that modern science and technology could be used for economic benefit or political intents without taking into account the consequences of the practices, due to the pressures of international competitiveness (MacLeod, 2001). It has already been seen that the market system tends to co-opt the innovations of science and technology to control national and international political relationships. It has produced repression for those whose national independence and sovereignty have been jeopardized (Rees, 2001; Shiva, 1997, 2000; Wackernagel & Rees, 1996; Wilson, 2002). For instance, the amalgamation of biotechnology and globalization has created a new ideology – biocolonialism (Kimbrell, 1996; Merson, 2001; Shiva, 1997). New terminologies such as bioethics, biodemocracy, eco-justice, biocolonialism, and bioimperialism reflect a tight integration of science and technology with social and political issues.

To critique the relationships among biotechnology, global economy, and human relationships, Vandana Shiva (1993) examines "the Green revolution" as a risky combination of genetic engineering and globalization. She writes:

> Dominant scientific knowledge breeds a monoculture of the mind by making space for local alternatives disappear, very much like monocultures of introduced plants varieties leading to the displacement and destruction of local diversity (p. 12).

Another example is the issue of patenting genes as property. Intellectual Property Rights (IPRs) legislation, suborned by lobbyists, has supported biotechnological and agricultural industries in the idea that genes can be patentable and commoditized (Kimbrell, 1996; Shiva & Holla-Bhar, 1997). When new genes are found by biotechnologists and patented by international corporations, the right to using the genes for any agricultural or pharmaceutical purposes are protected (i.e., privately owned) worldwide under the IPRs laws.

In many ways the world may be seen as 'shrinking' with the reduction in trade barriers, the expansion of capital, and the rapid transfer of technology in the age of globalization (Symonides, 1998). Open borders and trade allow corporations to look for new sources of natural resources as commodities: consequently, overexploitation and ecological destruction have been problematic in the ideal of global capitalism (Goldsmith, 1984; Gray, 1999; Hall, 1997; Klein, 2000; Mayor & Binde, 2001; Milton, 1996; Robins, 2000; Smith, 2001, 2002; Spring, 1998; Wackernagel & Rees, 1996). These concerns will continue not to be addressed in science education, however, as long as we hold science separate from the lifeworld in the sole realm of empirical objective knowledge and regard scientists in the labs and science teachers in the classrooms as solely pure (objective) knowledge seekers and transmitters.

The complex tension of science, technology, and globalization has challenged science educators in different ways ranging from preparing students as responsible citizens for the changes of global society to dealing with the pressure of test-oriented standardization of science curriculum. In response to the competitiveness of global market, science education has been subjected to the pressure of achieving more knowledge, more skills, and more technological competence in order to increase 'human capital' (Drori, 2004; Spring, 1998). Under this pressure, scientific literacy is expected to serve the interest of preparing students for the science and technological professions, as well as to prepare them to be good employees with the ability to utilize technology.

However, the separate and objective view of the nature of knowledge, science and technology becomes problematic in an environment where the controversial issues of scientific knowledge and its implications are increasing. In response to this notion, we could say that it is not science and technology that make the world a dangerous place, it is human minds that long for power, wealth, and control. Yet, this view can no longer justify the presentation of science as objective and value-neutral knowledge in the modern world. The modernist view of human nature and role of humanity and science might be turning us into passive agents when it comes to the knowledge and implications of science and technology. The passive and disconnected knowledge and action needs to be questioned in science education.

With the concerns of complex STSE relationships and our unfolding world, science education is to examine the ways in which human agency and scientific literacy can be incorporated and empowered in our daily practice for students to take an active and critical role in future society. To bring forth a humanistic and sustainable form of scientific literacy in science classrooms, in collaboration with our students, the traditional ways of science teaching such as objectified and text-oriented teaching are not inclusive and interactive to invite students as participants in the discourse of science and technology. The dynamic tension between objectivity and subjectivity in students' learning is often discarded. Who are our students in the discourse of scientific literacy? What needs to be questioned in the relationships of students' learning, knowing, and taking action for a sustainable world making? By exploring stories of learners' subjectivity in science classrooms, I will discuss these questions in the next chapter.

# III

## EPISTEMOLOGICAL ASSUMPTIONS IN SCIENCE: BINARY UNDERSTANDING VS. EMBODIED KNOWING

Modernism's binary separation between objective science and the subjective human realm has resulted in a view of scientific literacy that is separated from students' lifeworlds. Within this binary view, science teaching also denigrates learners' subjectivity in science classrooms, projecting a view of scientific knowledge as empirical and analytical. As an endeavor to challenge the separation of between objectivity and subjectivity in science learning, I attempt to explore learners' subjectivity in classroom situations (Chapter 4).

I expand the discussion of our binary modes of understanding the world from the subject/object split to the separation of knowledge and practice – a split that discharges our knowing of its ethical implications. To challenge this division, the integrity of knowing and doing is discussed in Chapter 5 in order to put forward an ethics of knowledge.

# CHAPTER 4

## RETHINKING SUBJECTIVITY AND OBJECTIVITY IN SCIENCE TEACHING

### Introduction

The discourse of empirical analytical science creates a binary understanding of objectivity and subjectivity. In the quest for objectivity, science education been implicated in the separation of scientific knowledge from the human subjective realm. Through being referred to as the antithesis of objectivity, subjectivity has been stigmatized as being constituted by emotions, feelings, and intuitions which are assumed to encumber scientific observations, reasoning, judgment, and explanation.

Accordingly, science teaching has emphasized objectivity and undervalued our subjective experiences of the world. The belief that scientific knowledge is built only with the objective side of our minds is empowered by this binary split between subject and object. Learners are recognized only for their abilities in logic and reason, not for their intuitive, creative or emotive minds. In this way it was believed that science could maintain objectively warranted knowledge. This view has divided the unity of human experience by splitting subjectivity away from objectivity. But how could such a divided way of teaching and learning develop students' understanding of science as knowledge connected to human values? How can this separated view of the nature of knowledge help us to mindfully understand a situation where human relationships are intertwined in complex ways with the issues of science and technology?

This chapter critiques traditional practices of science teaching that regard 'school science' largely as a body of content knowledge and the learner as the possessor of only an objective mind. Through contemplation of the separations inherent in modernist views of the nature of science, this chapter emphasizes students' subjectivity and objectivity as a unity in learning environments. Beginning with a personal narrative of my experience in a high school biology class, I will discuss the ways in which students become engaged in a learning situation and come to understand complex relationships of the learned object with their subjective experiences. The discussion will expand the notion of human subjectivity to include interconnected relations with others and the world – termed as 'intersubjectivity' and 'interobjectivity' - in order to ponder the ways in which our being and knowing dwell in a web of inseparable relationships in our shared world.

The human subject: Complex learner

*A biology class*

What is blood? When I was asked this question in my high school dissection class, I was confident of the answer. I knew what blood was. In biology class I had learned about blood – its components, blood circulation, blood's 'circuit map', the heredity of blood types and their scientific terminologies. Blood consists of blood plasma, erythrocytes, leukocytes, phagocytes, and thrombocytes. Hemoglobin is the color of blood: red. It is found in erythrocytes, and it combines with the oxygen in our lungs and is carried to other organs. I was proud that I knew so much about 'blood'. I felt ready for my final exams. But what did I really know about blood? What did I know about what it meant that blood circulated in living beings? I didn't realize that my text-oriented knowledge meant little in the grand scheme of things. I couldn't find any answers to those larger questions in a Grade 11 Biology dissection class.

I loved biology. My love of the natural world led me to enter with enthusiasm into biology class. I still remember my excitement and wonder in Grade 7 Biology when I first saw stomas on a spiderwort leaf through a microscope. I loved the awe-inspiring, eye-opening living world that I saw through the lens. The wonderful joy! In senior high school, I joined a special biology class that gathered once a week in the lab and did experiments under our teacher's guidance and support. The class activities engaged my whole-hearted attention. I grew accustomed to the distinct smell of the lab. There were jars of specimens floating in formaldehyde alongside the jars containing animal organs, a fake human embryo, and dead animals that had been stuffed and mounted – an eagle, a wildcat and some birds whose names I do not remember. All those engaging experiences in the lab were an invitation to an exciting new world.

By the time I reached Grade 11, I had dissected several worms, fish, and frogs in biology class. I approached zoology and animals in biology class with curiosity, wonder and some awe as well. My teacher was always well prepared and assigned us interesting lab work each week. His generosity and attentiveness always invited us into the lab and into science with comforting support and enthusiasm. Then one day, I recall:

> *The table was already set up when I got to class. I stared at the dissection tray in front of me that held tweezers, tissues, and an egg. My teacher came in and the day's lab started. "As you can see, there are eggs on your table. Each egg is in a different stage of embryonic development. Now we are going to see what embryos*

*look like at each stage of development. They vary in maturity. I don't know which one is which, so you can figure it out using your knowledge from last class. You have your tweezers. You can break the eggshell first and you will see the membrane inside of the shell. Go slowly when observing that layer and then move on to the embryo."*

*I started to break the shell with the tweezers. The shell was stronger than I expected. Trying not to break the membrane, I moved my hands slowly and carefully. Finally I opened the shell and reached the membrane I had seen many times in boiled eggs. I was still wondering what stage my egg was at and what would be inside. Then, as I poked the outer layer – the white, paper-thin membrane – something unexpected happened. Red, red, red liquid came oozing out of the hole, the tiny hole that I had just made in the white layer. It was blood. Eggs with red blood: Eggs are supposed to be white and yellow, not red, not with blood. I was not ready for this. I had never made a connection between living things, embryos and blood. Now I had proof that this living being had blood: red blood.*

*I felt numb. I was staring at the bleeding egg with the tweezers still in my hand. I was lost for a moment. I looked around to see what my friends were doing. They all seemed preoccupied. I held my breath and kept dissecting, moving my hands skillfully, not making any mess, following the instructions very carefully. I was constantly comforting myself. "I am dissecting in class. This is not new. I have dissected fish and frogs. This is not new. This is nothing. I can do it. I can do it." The "object" inside revealed itself little by little as my hands moved, and then, at the last moment, the whole object appeared in a flash.*

*I looked down at the whole embryo on the tray. The tray was messy with broken shells, blood and watery fluid from the embryo. I looked at the soggy "near-chicken" embryo. I could tell it was ready to hatch in a few days. I had "killed" this chicken. I took a deep breath and tried to calm down. I looked around. There was silence. During the silence, I tried to cope with the situation by separating myself from the scene.*

*Thinking through Cartesian mind*

Descartes (1641) begun with a position of radical skepticism that "all the things that I see are false" (as quoted in Cahoone, 1996, p. 34). Drawing on a radical turn toward doubt, Descartes tried to reach the truth of knowledge that was certain, distinct, and indubitable.

> I suppose myself that nothing has ever existed and all my memory represents to me is fallacious. I consider that I possess no sense; I imagine that body, figure, extension, movement and place are but the fictions of my mind. (Descartes, 1641, p. 34)

He separated mind from body and from the external world, positing that all knowledge from our sensory experiences is deceptive and unreliable and hence is little more than illusions and dreams. That is, none of the actions of seeing, touching, and sensing reality can possibly be true; it is only intuition that makes our perception possible and makes things truly exist according to Descartes.

From the perspective of the 'Cartesian Mind', my experience in the biology class was an illusion and a false phenomenon. During the dissection, to escape the all-too-real implications, I thought of the blood before me just through a Cartesian Mind. In the process, on some level, I tried to reject the reality of blood altogether; I tried to abject the blood, the life and the suffering it signified. Denial was my safeguard. To release myself, I refused to acknowledge 'the thing'. However, such rejection only alienated me from reality under the veil of such denial. The ignored symbols in silence came back to me as a resilient, unsolved disturbance.

*My teacher continued speaking about the maturation stages of the chicken embryos. I listened but felt numb. The image of the red blood on the pure white membrane was ever present; 'I' had removed the chicken from the shell, from life. I didn't know what was bothering me. It was just another dissection. It was a scientific experiment. I tried to comfort myself but was paralyzed and in shock. However the object that I was trying to make abstract and objective instead became more real, subjective, and amplified into my being.*

*I don't remember the rest of the class except my teacher's final comments, made in a sincere voice. "Life is very precious. Even though the eggs were not chickens yet, they once held lives. We need to appreciate their sacrifices for our lab work. Why don't we make a grave for them?" So we took the chickens out of the lab to the school's backyard and started a burial ritual. We dug a hole, put the sacrificed near-chickens inside and covered them with dirt and dried leaves. We* *picked up branches and made a cross. We stood still for a moment. My friend broke the silence: "Let's go. We're already late for class."*

Thereafter, whenever teachers taught about blood, I recalled most vividly in imagination the color of blood in the experience of my grade eleven classroom. What was the difference between learning about blood and experimenting with/in blood in the science classroom? I was not as objective or as neutral as was expected. I felt guilty for having emotions, feelings and subjectivity in a scientific context. Science is science and you are you. I should have understood the dichotomy.

After that, I became separated from what I did in the name of science. The objectivity of science exempted from moral consideration what I and others have done in the past, do in the present, and will do in the future. It exonerated me for the blood and the taking of life. But what of my lingering feelings?

*The chasm between objectivity and subjectivity*

In Descartes' time, the method of Doubt must have been a provocative way to understand the construction of knowledge and truth in the society. Albert Borgmann (1992) explains that in the "indictment of medieval disorder, the duress of daily life, the deadwood of tradition, and oppression of hierarchy and community" after the Columbian discovery, de-centered Earth by Copernicus, and Lutheran reformation of Christianity, there was an urgent need for a new fundamental, radical reconstruction of society (pp.22-23). Based on his reflection and concerns about the social problems, Descartes thrived to find a powerful procedure which could bring substantive accomplishments without dubious and deficient results. It was rationality. Under this circumstance, his method with reason was powerful to console people's shattered minds to cohere with trust and further to enlighten scientific method to reverse superstition and prejudice in the medieval time.

However, "at length Cartesianism asserted itself through science and industry," aggressively subduing nature with limited and isolated scientific minds (Borgmann, 1992, p. 35). In this process, the separation of logic and reason became a convenient necessity. It separated mind from body and depended only on 'cold reason' as the way of reaching the Truth (Damasio, 2000; Jardine, 2000). The thinking subject was separated from the surroundings. It was a fundamental error in that the separated self is incapable of seeing the truth that lies in the middle of the relationships of the world.

Human perception/cognition cannot be separated from physical and mental interactions with the perceived; objects or phenomena (Capra, 1975, 2002; Maturana & Varela, 1987; Merleau-Ponty, 1945/2002). In the process of knowing, there is no separation between objects and subjects, body and mind, and the knower and the world. For instance, when children learn watershed, their learning is based on their lived experiences with rain, snow, stream, forests, towns, and life styles which their bodies and minds are interconnected to the surroundings. They are engaged in learning with logic and reason, emotions and feelings, and values of the world through their experiences of the world. In the knowing which is the unity of the learner, the object, and the world, there does not exist solely independent objectivity or subjectivity in our knowing but only the interrelationships of the two domains.

*Re-thinking subjectivity in pedagogical settings*

> The naïveté of talk about 'objectivity' which completely ignores experiencing, knowing subjectivity, subjectivity which performs real, concrete achievements is...no longer possible, when life comes on the scene. (Husserl, 1952, as quoted in Gadamer, 1960/1999, p. 249)

A subject/object dualism produces often dualism into body and mind, and logical and emotive minds. There is a 'twofold dichotomy'. By subjugating humanity's feeling and sensing subjectivity in scientific contexts, science education acclimatizes students to the separation and suppression of subjectivity. It obscures or ejects the embodiment and autonomy of *inner*-actions in learning situations. Under the circumstance of suppressed subjectivity, knowing is lopsided and insufficient to cope with the rich complexity of life situations because the reflexivity of whole minds has been handicapped by a refusal to acknowledge one entire domain of human knowing of the world.

The suppression of subjectivity can cause students' 'absent presence' in science classrooms. Students are physically present but not attentive. We have lost their embodied minds in our desire for the certainty of text-oriented knowledge and for the standardization of 'success' (Palmer, 1998). While we hope that "tests and standards will make [them] an educated citizenry, we lose sight of the painfully beautiful, impossibly complex students before us" (Taubman, 2000, p. 27). Alfred North Whitehead (1929) wrote,

> The mind is never passive; it is a perpetual activity, delicate, receptive, responsive to stimulus. You cannot postpone its life until you have sharpened it. …Whatever interest attaches to your subject-matter must be evoked here and now; whatever powers you are strengthening in the pupil must be exercised here and now; whatever possibilities of mental

> life your teaching should impart must be exhibited *here and now*. That is the golden rule of education and a very difficult rule to follow. (p. 6, Italics added)

In reality, students' subjectivity has never been absent. It has been only remained largely unnamed, unrecognized, and unsaid. In the knowledge we are learning, there our subjectivity is engaged. Its presence needs to be recognized with appreciation. Recognition and celebration of their subjectivity can invite students to learn science in their life contexts. It can cultivate the integration of scientific knowledge with human agency, and allow us to ponder the justifications for our actions in ways not supported by objectivity and separatism.

From separation to interrelation

A disembodied rationality could not understand my relationship to the egg and the dissecting scene. It could not understand the unity of my touching, seeing, thinking and feeling body. As my self as a whole was involved in the phenomenon, there was no separation between body and mind but only embodied complexity. For me, there was no demarcation between subject and object but only interrelationships. Within this integrated unity, subjective experience goes beyond individualistic realms to understand collective knowledge and the ethics of action. How does subjectivity transform itself through interdependent relationships with others? Within the unity of self, how does one construct knowledge of others, situations, and the world? More importantly, how can we develop rich understandings of interrelated human-world relationships with our students in science classrooms? In exploring these questions, I ponder intersubjective and interobjective relationships in the pedagogy of science teaching as means to cope with the separation of current notions of scientific literacy from human lifeworlds.

*Intersubjectivity: The I-Thou relationship*

In intersubjective discourses, a subject experiences the other as an analogy of the self and develop his/her understanding of I-Thou relationships. 'I' starts to apprehend the other as an object of perception. Then empathy comes into play in this process of recognition and apperception of another consciousness (Buber, 1958; Crossley, 1996; Dallmayr, 1981; Gadamer, 1960/1999) and I begin to (intuitively, empathically, tentatively) understand the other. I-Thou relationships, therefore, take place in the shared space where the 'I' as transcendental Ego – *the primal* I, not just *an* I – expands its boundary to connect with and even imaginatively merge with other subjectivities (Gadamer, 1960/1999). Based on the transcendental ego, we share mutual and communicative experiences of the world. We create spaces for intersubjectivity; dialogical and reciprocal common grounds in our human relationships (Davis, 2004; Markova, 2003).

This concept of the transcendental ego has similarities with the Buddhist notion of self. The notion of 'co-arising' offers the insight that every living and non-living being is co-emerging and co-existing in interdependent relationships with other beings. The self is neither an entity, nor a substance, nor an essence but it is a dynamic process of co-emerging relations (Bai, 2001; Galin, 2003). One cannot exist without those relations.

D. T. Suzuki (1960) suggests that "the Self is comparable to a circle which has no circumference. It is thus *sunyata*, emptiness" (p. 25). In the Buddha's teaching, emptiness of self means not a passive and nihilistic embrace of nothingness but a mindful awareness of the interdependent co-arising and impermanence of being in dynamic relations. The notion of *sunyata* (emptiness) and *an*

2003; Fisher, 2002; Hanh, 1999). When one breaks the boundaries of one's self and realizes one's position in a complex web of connections to the world, the self becomes empty and full at the same time. Suzuki (1960) explains that understanding this emptiness is a way of understanding our inter-subjective relations to the world.

In this transformed holistic view of the relations between the transcendental self and the world, the self is dissipating within other beings and there are no boundaries between the self and others; therefore, the self is groundless with mindfulness – it is a 'selfless self' (Varela 1999; Varela, Thompson, & Rosch, 1991/2000). Expanding human beings' inter-dependent relationships to other human beings, other species and the natural world, the Buddha's teaching also provides a fundamental sense of a mode for ecological living in this world.

In this intersubjective understanding, therefore, we learn with others. The scientific knowledge that we construct is part of our being in the world. It embraces our inter-subjectivity as we search to know and to learn the world in front of us. Without recognizing mutuality and empathy, it is difficult to challenge the current duality in scientific knowledge. This challenges us to find ways to expand our notion of scientific literacy in order to support science teaching that is itself – and helps our students to become – more connected, participatory, and responsible. In modern society, it is critical to bring an intersubjective understanding into science and learning so that we understand the meaning of science education within a framework of human knowledge and practice.

Some make the criticism that in intersubjective discourses there still remain the collective hallucinations of human-collectives and anthropocentrism because such discourses emphasize human-centered values and ideas and lack the inclusion of our natural surroundings as equal participants in our living relations (Crossley, 1996; Moghaddam, 2003). These critics argue that for this reason the discourse of intersubjectivity falls short in explaining how the world of objects comes into the relationships of subjects. How can the discussion of intersubjectivity expand its understanding to the natural and non-human world? How can we talk about our relationships with objects which do not have subjectivity? The responsibility for our relationship with the world of objects falls heavily on our own actions.

Nick Crossley (1996) explains that the I-Thou relationship extends its domain into a collective level of the world through our physical participation. The space between participants links us into an irreducible structure - *interworld* - which encompasses not only human subjects but also objects, for example, animals, plants, and landscapes. Crossley claims, therefore, that intersubjectivity can expand its understandings to include human and non-human relationships. With this understanding as a basis, I will expand the concept of intersubjectivity further by introducing Bruno Latour's notion of interobjectivity to emphasize the ecological relationships between human beings and the environment.

*Interobjectivity: Human and non-human relationships*

In modern society, the disposition and engagement of objects greatly affects our everyday relationships. That is, our relationships are based not only on human – human but also human –non-human environments. How do the non-human beings such as animals and plants, artifacts, machines, highways, and internet networks shape and reshape our understanding of the world? The world of objects which has been understood as a realm of passive, static 'things' needs to be reconsidered as a realm of interactive participants in modern relationships. This opens up a possible way to approach discussion of the roles of science and technology in relation to social and environmental ethics.

Interobjectivity is the interaction of an objectified 'I' and a subjectified 'it', which means 'I' is no longer different from a non-human being. This understanding of subject-object relationship introduces non-living beings such as artifacts, technologies, systems, landscapes, and the environments as significant and indispensable factors of the world. In interobjective relationships, all beings are active participants that bring forth the world together. This view suggests that we also situate our selves in the relationships with the objects of the world to understand the meaning of the world.

In the interobjective view, we understand science and technology also as active actants in knowledge making of the world. Beginning with the notion of science and technology as active participants in human and natural worlds, I question the ways in which the products and practices of science and technology participate in the unfolding world, and ponder how we as human beings take part in these dynamics through knowledge making and practice/praxis. I further question whether there are any possible ways for us as human actors to orient the unfolding world to become a more ecologically-sensitive and humane one. In a pedagogical sense, this question also challenges us to teach with/in and an ecological understanding of the world.

It is noteworthy to acknowledge the notion of interobjectivity in Maurice Merleau-Ponty's work, *Phenomenology of perception* (1945/2002). In his work, he emphasizes the reciprocal interactions between the I and its surroundings which influence and shape the pattern of perceptions and the actions of being. Through interactive participations, the I changes the world and the world also changes the I. In the realm of interobjectivity, the I, transcendental subjectivity becomes an *interactive participator,* connecting between human beings and their surroundings and living and non-living systems. In the mutual participatory relationships of interobjective worlds, we cope with the separation between subjects and objects, i.e., human beings, technologies, and the environments to understand our beings in this modern world (Capra, 1996; Maturana, 2000).

Bruno Latour (1996) argues that it is important to recognize the interactions inherent in the social structures of "framework" and "network" in order to understand modern relationships today. He claims that to understand the complexity of human *inter*actions in the modern world, we need to look into things/artifacts. "Human interaction is most often localized, framed, held in check. By what? By the frame, precisely, which is made up of non-human actors," says Latour (1996, p. 238). In treating things as social "actants" – transportation systems, service counters, radio signals, computer networks, and other technological objects and systems - we need to understand the complexity of human/non-human relations (Portugali, 2003). Latour further explains, "instead of clarifying even further the relations between objectivity and subjectivity, time enmeshes, at an ever greater level of intimacy and on an ever greater scale, humans and nonhumans with each other" (Latour, 1999, p. 200). His ideas illuminate the active and inevitable participation of objects in the historicity, framework, and network of modern technological discourses. Interobjective understanding expands our relationships to the natural and technological environments and suggests that we need to understand our ethical and ecological participation in the world's unfolding.

Whereas intersubjectivist discourse focuses on interrelationships between subjects, interobjectivist discourses emphasize our reciprocal participatory relationships in the natural and non-human worlds. Each discourse has its own strengths to contribute to the epistemology of scientific literacy; intersubjectivity helps us to understand interpretive and reflective human knowledge, and interobjectivity the enactive ecological framework of the world. Both discourses help to build important foundations to understand the ethics of knowledge and action in order to enable us to live and teach mindfully.

Ecopedagogy: Science teaching reconnected

David Jardine (1998) has introduced the notion of "ecopedagogy" in support of ecological science curricula. Ecopedagogy is neither a simple application of scientific knowledge nor an introduction of ecology as a special topic in school curriculum. Rather, it is the full, healthy, and wholesome presence in the living of students and teachers at the very site of teaching and learning. Within the immediacy, interdependency, and intimacy of ecopedagogy in science learning, science is not all about being dissected, mathematized, and objectified. It is a paradigm of the intersubjective and interobjective relationships of our being and living. Acknowledging students' bodies, lived experiences, and resilient minds, teachers' presence can also emerge at the very site of classroom dynamics. It is the pedagogy of co-emergence in ecological science teaching.

I think again about the burial ritual proposed by my teacher. I am grateful that he was *with* us in the situation. There was a moment of silence when he didn't know how to return the students' troubled gazes. I could see confusion in his eyes. But then he knew exactly what we needed. He allowed us to express our feelings as full human beings through showing his feelings toward the dead eggs and his students. With the burial ritual, life went back to its original place and brought life back to us. We became re-connected to life, nature, and our own beings. In the midst of the confusion of life and the abstraction of knowledge, my teacher's attentive pedagogical action taught us the life of science. His mindfulness was in a mode that blended pedagogy of the intersubjective and interobjective worlds, unfolding the web of interconnected lifeworld and natural world.

From that class, I learned something about the relationships between life, science, human beings and the world. I learned that science could incorporate human ethics and a genuine respect for life. I learned how a teacher's pedagogical immediacy and caring attentiveness could appreciate students' subjectivity and acknowledge their being fully-human in science learning. It deepened my appreciation for science. It encouraged me as a student to learn and be 'in science' with my subjectivity. In this example, the interdependence between subjectivity and objectivity in science learning made the meaning of scientific knowledge and action possible. Dwelling in this world resituates us as human beings and enriches our scientific knowledge with life connections.

My teacher's voice, the image of the dead animals, the color of blood and my body movements now manifest themselves, along with many of my other experiences in relation to science and learning, in my own science thinking and teaching. Science education now invites me to bring interconnectedness into the classroom, to encourage me to become fully human, to learn with both epistemic and emotive knowledge, and to utilize embodied learning through re-thinking science as a way of living.

# CHAPTER 5

## ETHICS AS THE UNAVOIDABLE RESPONSIBILITY OF KNOWING

### Introduction

Under a binary (i.e. split between mind/body and subject/object) understanding of science, the intersubjective and interobjective understandings are unrecognized, estranged, and shattered. Within such a divided vision of scientific knowledge and human lifeworlds, concern with the ways in which science is being practiced in our relationships are considered irrelevant. Since scientific knowledge is taken as a pure conceptual domain, it is freed from subjective practice and human values. In other words, science seeks for nothing but decontextualized knowledge, and the social and ecological implications of that knowledge are not considered to be part of the subject matter of science.

In addition to the splits between mind and body and between subjective and objective knowing, a binary conception of the nature of science leads to a split between having particular scientific knowledge and the ethical and human implications of actions taken as a result of that knowledge. This binary division between knowledge and action is a consequence of a conception that separates knowledge held in the mind from knowledge as embodied and emergent in our actions in the world.

This leaves us separated from responsible actions that would otherwise follow from knowledge. For example, knowing the formula and being able to write down equations for the chemical reactions of certain chemicals that would harm natural organisms and human health over time, on the one hand, and on the other, choosing to use products containing those chemicals are separated into different dimensions of knowing and doing. Despite the disconnection between the two dimensions, we still possess knowledge about the chemicals. We seldom question what our claims to know mean in this circumstance. The binary separation of knowledge from its consequences and implications often leads us to ignore the immature and irresponsible application of knowledge in modern scientific and technological enterprises.

In the interactive relationships of the world, however, knowledge is already interlocked with its practice and consequences. In their participation in making, holding, evaluating and using knowledge, human beings' actions are already disposed toward responsibility. As Federico Mayor (1999) suggests, "the possession of knowledge carries with it moral obligation" (p. 166). The ethical relationship between knowledge and action needs to be recognized in a more modern and responsive view of scientific literacy. With this understanding as a place to begin, this chapter examines how our knowing and doing can be integrated in ways that better enable us to discuss and enact the ethical dimensions of knowledge.

As science educators' conception of scientific literacy aims to help students understand the links between knowledge and responsible decision making and action, it becomes necessary to challenge separated views of knowing and doing. In order to complicate binary understandings of knowledge, this chapter introduces the concept of the ethical dispositions of knowledge, drawn from two sources. The first is Varela's (1999) notion of "immediate coping." The second is an exploration of the Confucian conception of the necessary integrity in the connection between knowing and doing as understood in the concept of "cheng." In each of these concepts, ethical knowing can be found in a tight relationship with action-taking.

Discussion of the integrity of knowledge encourages us to ensure that our conception of scientific literacy requires *inter*active and *pro*active participation in our everyday living as implicit and explicit consequences of knowing. When knowledge is understood as the unity of knowing and doing, we cannot claim to possess scientific knowledge without authentic integration of the conceptual and enactive dimensions of knowing. As an initial approach to questions about the ethics of knowledge, the next section discusses the ways in which our bodily actions and knowing are interrelated and embodied in everyday situations.

## The ethics of knowledge

### *Varela's "Immediate coping"*

How do our knowing and doing relate to each other on an everyday basis? On what basis do we act in the situation at hand? In *Ethical Know-How,* Francisco Varela (1999) explains how we cope with the situations that we encounter in our everyday lives. He indicates that we already know how to do things in everyday situations on the basis of observed recurrence. He calls our readiness-for-action, *microidentity* and every specific lived situation, *microworld.* Each of our microidentities responds properly to a particular microworld and we are constantly moving from one microidentity to another. For example, we already know how to use a spoon (microidentity) to eat soup (microworld) from our previous actions. When we develop another action to cope with another situation, we become experts in that situation.

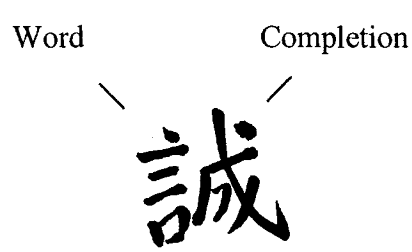
He points out that "In general, "who we are" – the pervasive mode of living – consists of *already* constituted microworlds" that have been founded throughout our lives" (p. 10). We are also confronted with "breakdowns," however, that challenge our decision-making and behavioral patterns. During these breakdowns, our behavioral stance is selected or a microworld is brought forth to analyze its appropriateness to the situation of the world. In this case, it is possible to question which stance or microworld is going to best respond to the very situation of breakdown.

Varela emphasizes the notion of "immediate coping" during breakdown situations when we are not experts of our microworlds anymore. Immediate coping means that we can cope with a situation at hand, even a novel situation, with appropriateness and immediacy. This is where we are challenged with responsible decision making and with taking action in immediate situations. Varela explains that immediate coping is not a simple or reflexive action but a process that needs "the longest evolutionary time to develop" (p. 18). It is a process of embodying our knowing and learning over time. This act of immediate coping takes much wisdom and authenticity in order to evaluate the situation with moral judgment and immediately understand the consequences of action. Immediate coping exemplifies highly skillful and mindful decision making and action.

*How can I develop my immediate coping to be wise and appropriate? What does it have to do with our knowing and knowledge after all? How is immediate coping related to the integrity of a good person?*

*Cheng: The integrity of knowing*

The Chinese character *Cheng* embraces a way of being and living that is embedded deeply in the wisdom tradition of China and Korea. This word consists of two parts: the left side means *word* and the right part means *completion*; therefore, this character as a whole refers to 'integrity'. That is, integrity might be described using the Western phrase 'her word is her bond': what is said and known is also what is done and completed.




***Integrity***

Living with this word, my life has been a process of becoming a 'person' who lives with integrity and in harmony with other beings in the world. This person carries responsibilities for her words. To be such a person, my knowing should be completed in my doing. I attempt to complete my words and thoughts in my actions. This is the person that I need to/want to *become*.

> Words can be actions only to the extent that the co-authors give them power to act through personal commitment and taking a stance. The loss of commitment to one's words could result in the author's loss of self-identity and authenticity. Dialogicality implies contract; responsiveness and responsibility. There can be no word without a speaker – words have their history. There can be no word without the self. (Markova, 2003, pp. 257-258)

Personally, I find it very difficult to maintain integrity in all of my living since I am only a weak and confused human being. My parents used to tell me as a youngster that I should strive to become a 'person' first rather than joining a profession. "You could be a good professional without any integrity but your life would be very confusing and trivial. Whatever your profession would be in your future, you should strive to become a person first." In the Confucian tradition, to be a person connotes more than a human being. The concept bears connotations of responsibility, wisdom, and justice. It takes a good person with integrity to live in this world gratefully and graciously. To be a person first is such a huge concept of being and living. I didn't realize how difficult it would be to live up to my parents' lesson when I was little. I assumed I would become a person naturally as I grew up. As an adult, the more I try to become a person, the further from me it seems to be. I have learned humility in the processes of this on-going quest, but it all helps me cultivate personhood in the journey of becoming.

*The harmony of the knowing body and doing mind*

Varela (1999) refers to the Confucian tradition, citing Mencius' argument on finding the 'middle way' and on the harmony of intelligent awareness to explain the concept of "immediate coping" more clearly. Varela states, "the intelligent awareness...[as Mencius describes] takes a middle way...intelligence should guide our actions, but in harmony with the texture of the situation at hand" (p. 31). Varela claims that ethical expertise means knowing how to respond appropriately and immediately to *a situation at hand.*

Situatedness is a key factor in immediate coping. For example, let us suppose that you see a child crying on the street on the way to run an errand at the post office. You think that the child needs some help, but you have only a few minutes before the post office's closing time. What would be your reaction to the situation? This situation has no reference in your existing "microidentity" and "microworld." Your thinking is oscillating but it is finally necessary to make a decision embodying whatever you think would be the most appropriate at that moment. You immediately cope with the situation at hand. We are confronted with various breakdowns every day like this. In each case, we try to respond to the situation in harmony. We attempt to make our immediate coping decision both appropriate and moral. This practice eventually becomes embodied in our microidentity (readiness-for-action) and this helps us to be ethical experts in the 'breakdowns' that occur as a result of life situations.

To understand the relationship between harmony and immediate coping as a way of doing/living ethically and wisely, it is valuable to look into two key concepts in Confucianism: Li (禮) and Yi (義). These two concepts are intermingled in the concept of middle way/harmony, person making/becoming a person, and immediate coping/ethical expertise; therefore, it is necessary to explore these terms.

Li is about our outer actions while Yi is about their internal meanings or significations. Li is translated as 'rites, ceremony, decorum, manners'. It is summed up as 'ritual propriety'. Li refers to the general posture that one strikes and pursues. Ritual actions and the body are interconnected and the body of the rituals can be the root that supports the innovation and creativity of cultural traditions.

Yi means righteousness or right meaning. Yi is intrinsically intertwined with the contexts of situations. Yi is a standard relating to decision making or conduct; therefore, it is fundamental to the dynamics of person making (Hall & Ames, 1987).

In Confucian theory, learning through ritual actions is very important to person-making. The follow example of how a child learns respect manifests the relationships between Li and Yi. Before a child knows the concept, 'respect' or 'deference to the elderly', the child starts learning certain ritual actions such as taking a bow or passing things to people with both hands. In Korean traditions, these are the ways of showing your respect to the elderly. The child does not know what it means at that time but they learn to act in certain ways from their parents and other elders. By repeating the action, one slowly learns the concept of 'respect' and comes to know the appropriate situations in which to take a bow and pass things with both hands. Over time, the child internalizes the virtue of respect. When the child sees elders next time, the child takes a bow out of respect and this is the moment when one's ritual action matches with one's internal understanding of meaning – the moment of integrating Li and Yi. Taking a bow becomes a ritual of respect and the child embodies the meaning in her action.

To understand this concept in a Western context, we can think about the example of 'lining up' in a public place. Children learn to line up (Li) from their parents when they use public washrooms before they know the social conventions of keeping order and respecting others (Yi). They embody this ritual with its virtues later on and they always line up and appreciate the order and convenience when washrooms are busy.

There is no way to distinguish outer actions from inner meaning or *vice versa* when Li and Yi are intermingled and practiced in harmony. In this respect, actions take place with no time to engage intentions because the intentions are actions and the actions arise 'naturally' from the situations that one faces. This is the moment when intelligent awareness is accomplished in harmony according to Mencius. Harmony or 'middle way' is about one's self but also about the relationships between time and space. It is when we reach harmony and middle way that the moment of knowing is achieved. An 'exemplary person' in Confucian theory and a person who possesses ethical expertise in Varela's theory refer to the same kind of person – one who has the *wisdom of harmony and integrity* and always conducts him- or herself appropriately.

Their actions are immediately performed in the situation at hand because such people are themselves in their actions and ethical meanings. Confucius once said that "becoming an authoritative person emerges out of *oneself*-how can it emerge out of others?" (Hall & Ames, 1987)

Knowing needs to embody its meaning in rituals - i.e., our behavioral actions and knowledge allows us to cope with a situation appropriately and with harmony. When rituals are internalized, meanings become integrated with ritual actions and, in turn, they become us. This process requires much time and effort. There are many obstacles involved in internalizing and integrating Li and Yi in our selves because all learning and knowing processes require patience and often pain in order to become a person of integrity and to live in harmony.

With these understandings of the harmony and integrity of knowing, I understand that our knowledge is not only conceptual but also embodied through our actions. Without such integration and embodiment, we cannot claim that we really know nor that our knowledge is truly understood and valued. Our effort to cultivate integrity in our actions is the ethical dimension of knowledge. This notion also encourages us to question the ethics implicit in our conception of scientific literacy.

This means we will need to take into consideration the relationships between scientific knowledge and decision making and action in the context of modern science and technology.

*Mindfulness in one's actions*

At this point, a question arises in terms of the dynamics of decision making and action. Do our actions always incorporate our knowledge? Are they always based on our consciousness? For example, how can we understand "immediate coping," which does not even call our consciousness at the moment of decision making and action? We often assume that we make our decisions based on the knowledge and logic that we 'possess' and use as a means of judging our actions. However, we also experience ourselves making decisions that depend more on feelings, emotions, and bodily habits than on the situation at hand. Sometimes we do not know why we acted 'this' way instead of 'that' way. Latour (1999) mentions this complexity of the 'action taking moment' as follows:

> I never act; I am always slightly surprised by what I do. That which acts through me is also surprised by what I do, by the chance to mutate, to change, and to bifurcate, the chance that I and the circumstances

> surrounding me offer to that which has been invited, recovered, welcomed. (Latour, 1999, p. 281)

Consciousness is only a little part of the tremendous process of human relations with other biological bodies and the surroundings (Lakoff & Johnson, 1999). Steven Johnson (2004) and George Lakoff and Mark Johnson (1999) indicate that many of our actions depend on our precedent memories which are embedded in the unconsciousness and do not always engage consciousness to represent the memories of knowing. Davis, Sumara, and Luce-Kapler (2000) explain that consciousness is "often too small to accommodate both engagement in an activity and awareness of one's self or one's actions. In fact, it is often reported that exemplary performances and profound engagements correspond to *forgetting* of self" (p. 7). In this regard, our decision-making and action are not always combined with our consciousness.

From this perspective, continually practicing virtues and good behaviors is one of the fundamental ways to conduct ethical actions as discussed in Varela's immediate coping and the Confucian notion of rituals. Similarly to the way in which repeated practice of certain stances and movements in a martial arts class will make such performances automatic and unconscious in a flawless tournament performance, enacting right choices and practicing virtues will lead to ethical expertise and to appropriate immediate coping decisions. We also need to practice our habits of mind through mindfulness to bring forth the unconscious into consciousness in our decision making and action (Lakoff & Johnson, 1999). The role of mindfulness is "to enable the mind to be fully present in the world. The goal is … to be fully present in one's action, so that one's behavior becomes progressively more responsive and aware" (Varela, Thompson, & Rosch, 2000, p. 122). We mindfully question our thoughts and action in the situation at hand in order to bring forth the integrity of knowledge and action.

When we relate these observations drawn from immediate coping of embodied ethical action to scientific literacy for contemporary society, we find that the integrity of knowledge and practice needs not only to be in the scientists' laboratory work but also in the everyday lives of citizens'. In this sense, scientific knowledge needs to be taken into consideration in terms of the integrity and mindfulness of action. This challenges our epistemological assumptions about science and science teaching in fundamental ways.

Ethical understanding of science education

The notion of ethics can be applied to our being as a teacher for a moment to question how our being and teaching bear ethical relationships to students in our science classrooms. As Emmanuel Levinas (1985) describes the idea that there is a critical moral commitment in the constitution of the self, my responsibility for students and science education is already embedded in my being. Levinas writes,

> My responsibility is untransferable, no one could replace me. In fact, it is a matter of saying the very identity of the human I starting from responsibility, that is, starting from this position or deposition of the sovereign I in self consciousness, a deposition which is precisely its responsibility for the Other. Responsibility is what is incumbent on me exclusively, and what, *humanly*, I cannot refuse… Such is my inalienable identity of subject. (pp. 100-101, italics original)

Levinas (1989, 1993) addresses the concept that in intersubjective relations, we are held *hostage* in carrying our own ethical burdens toward others.

However, living with this responsibility is not an easy task. When I look at my pedagogical efforts - disintegrated and stumbling in my own actions - I feel panicked, helpless, and even false to my self. And yet, I understand that this is what Levinas explains to us: the ethical burden of being "hostage" to our relationships. I need to learn how to celebrate this burden as an integral part of the privilege of being a teacher.

To continue to discuss the process of being a mindful teacher, in Chapter 6 I will explore a hermeneutics of science teaching and curriculum as a way of practicing pedagogical integrity. Within the on-going process of being and becoming a person with *cheng* (誠 - integrity), hermeneutic pedagogy will help me begin to understand how to embody students and their worlds in science classrooms and how to act with integrity in pedagogy through my teaching.

In considering hermeneutic pedagogy, I need to understand that my questions about scientific literacy will be raised and understood in the midst of the relationships among and between myself and my students. Through my attempt to understand hermeneutic pedagogy, I hope to learn how to position myself as teacher and researcher in the middle of the dynamics among children, curriculum, classroom, and society.

# IV

## RESEARCH RATIONALE & METHODS

To understand the possibilities of more embodied notion of scientific literacy that emphasizes the harmony of knowledge and the lifeworld, I aimed to practice a mindful pedagogy of hermeneutics in my research. Hermeneutics introduces mutual and dialogical modes of understanding as ways to interpret and reflect on the research texts with the researcher's horizons as a 'place to stand' (Chapter 6). With hermeneutic pedagogy as a starting point, research questions and methods are developed in Chapter 7. The research contexts are examined to allow the representation processes involved in writing this dissertation to embody the research texts in their particular vintage of time and place.

# CHAPTER 6

## A MINDFUL PEDAGOGY OF HERMENEUTICS

Introduction

As I came to understand scientific literacy as embodied knowing, I was confronted with my old habits of thinking and teaching science based on a binary understanding of the nature of knowledge and science. My earlier separated and objectified teaching was challenged as I tried to understand how I could understand and bring forth a balance of objectivity and subjectivity and embody the integrity of knowledge and action in my science teaching. My mindful awareness and critical mind are essential in allowing me to pay attention to the meaningful stories and interactions being shared in classroom dynamics. To look more deeply into the stories of science education, I aimed to practice my research on the basis of the dialogical and mutual understandings of hermeneutics.

As I tried to understand the stories of children, science curriculum, and society, I kept encountering the questions "who I am as interpreter in the stories?" and "on what grounds do I stand to retell the stories to others?" These are questions about how I attempt to sensibly and sensitively position myself as a hermeneutic researcher in the relationship between the researcher and the researched in order to understand the meanings of stories, and recreate other stories to tell. In order to be aware of the dynamics that the relationship generates, it is necessary that I examine my own 'horizons', which implicitly and explicitly take part in the research process, through questioning, interpretation, and reflection. In this way, I strive to contextualize my understanding of the research text on the ground of my own experience: to construct a 'place to stand' from which I can begin to tell the research stories.

Hermeneutic understanding

*Mutuality of understanding*

As we try to understand the meaning of own being in the world, we are always interpreters of the world. We understand the world through the situations, relationships, and interactions in which we participate. When we understand a situation or thing, we know how to be and live with it. We become attuned, prudent, and caring in the situation. In the process of our understanding, the other being is vividly present. I realize that the other being actively creates, assures, and reshapes the meaning of my being and action in the world. For example, in classroom situations, I become a teacher through children's presence. Through the interrelated mode of being between us, I come to understand children and the pedagogy of science teaching. But, what do I mean by 'understand'? How do I know my 'understanding' truly understands children and their unfolding words/worlds? As I enter hermeneutic research, the meaning of understanding suddenly becomes very difficult to reach.

The hermeneutic tradition suggests a way of *understanding* in a deeper sense than the unified actions of observing, characterizing, and conceptualizing an object or a phenomenon. Hermeneutic understanding is concerned with the relationships of people, time, and place at the very site of the thing or phenomenon. David Smith (2003 b) indicates that our attempts to explain or interpret *the thing* cannot be separate and distinct from the world because it is always already part of the relationship, the intersubjectivity. Even though we interpret the thing through our subjectivity, the interrelatedness of being, the transcendental 'I' leads our understanding to be communal and intersubjective. Understanding emerges not only from self-consciousness or self-knowledge but from the mutuality of inter-being and communicative interactions on our shared ground. To understand is to learn a relationship and to learn of the dependability of being in our shared stories.

In a pedagogical sense, to understand means to cultivate mutual trust, care, and respect between teacher and students. Traditional hierarchical teacher-student relationships are not well adapted to create open and mutual environments. In top-down relationships between teachers and students, the mutuality of hermeneutic understanding becomes a challenge. During the research process, it is vital for me to build up open and trustful relationships in order to understand children and their stories.

*Understanding through dialogue*

A mutual conversation - *dialogue* - is a significant means of approaching hermeneutic understanding. The interpretation of a text (including a 'world as text') is always a dialogical and dynamic encounter. Schwandt (2001) reminds us that "as interpreters [researchers], we participate in, open ourselves to, share in and listen to the claims that the object [of conversation] is making on us" (p. 194). Through dialogue, both the researcher and the researched actively participate in understanding and meaning-making.

Accordingly, it is vital to incorporate dialogical relationships with children as a means to cultivate interactive and mutual understandings during the research. Strategic dimensions such as interviews, informal conversations, classroom discussions, and story sharing are helpful. So too is the importance of creating a contemplative place for thoughtful reflection at the very scene of story sharing.

Taking this view in a classroom setting, I question how often and how effectively I as a teacher participate in dialogue with students in order to understand their learnings. In science classrooms, we seldom enter into dialogue - rather we more often participate in a question and answer relationship. The questions always await the right answers from students.

We enunciate such grades as creativity of knowledge making, thoughtfulness of interaction, and contextualization of life experience are goals, but perceived time constraints always keep us trying to move on to the next question. In textbook-oriented learning environment that is focused on empirical and analytical science, dialogical relationships between teachers and students are often neglected or minimized. These textbook-oriented science curricula – which are very dominant in our profession nationally and internationally - challenge our intention to teach science using a hermeneutic pedagogy. Its objectivist approach cannot invite into the classroom our and our students' human subjectivity and the embodied meanings of scientific literacy in our lives. Under these circumstances, practicing hermeneutic pedagogy is a challenge in science classrooms. It is critical, however, to look into the possibilities of a view of scientific literacy that will include children's lifeworlds in rich and connected ways. My endeavors to invite children's lived experiences and stories and to be attentive to their presence in the classroom will be important for this research process, and as a way of rethinking my teaching of science.

Interpretation and the researcher's horizons

To approach the mutuality of hermeneutic understanding, the researcher puts forward her own "truth" in the conversation with the researched. In our efforts to bring forth the truthfulness of one 'self' to the other, the researcher realizes that her own lived experiences and understandings of the world implicitly but dynamically interact with those of the researched in the processes of interpretation and reflection on the dialogue. Within this interactive understanding of hermeneutics, how do I situate myself as researcher to understand and retell the stories of children to other people?

During the processes of interpretation and reflection, some stories resonate with me more than others. Some seem to have more significant voices than others. I choose particular threads of children's stories as well as mine to interweave a meaningful story that is (in some sense) 'ours'. But on what basis do I decide to emphasize one aspect over the other? Is my decision-making based on prejudices that I need to avoid as a researcher? What does hermeneutics suggest in terms of ways to understand this process of interpretation? To explore the complexity of the researcher's engagement in the research process, the next section explores the notion of 'horizons' in hermeneutic perspectives.

*Interpreting (with) the researcher's background*

I think about the stories that have constructed the person I am today. The stories of my childhood river and of dissecting the egg are intermingled in my understanding of science education. My concerns about the dis-integration between modern science and its ethical implications have grown with/in those stories, leading me into my questions about science teaching. I realize that I have been drawn into the topic of scientific literacy for contemporary society. I as a researcher have already been positioned in the research questions by my background and pre-understandings of the world.

As David Geelan (2004) states "the researcher *qua* researcher is not a *tabula rasa,* a researcher comes to the field with a set of experiences – of teaching, research, and life in general – that strongly inform his or her interpretation and understandings" (p. 37). We are always interpreting phenomena with our prejudices (or prejudgments or preconceptions) that come from the tradition of which we are a part (Schwandt, 2001). In this respect it is critical for interpreters to be mindful of how their own background is situated in certain traditions, languages, and experiences as their research develops.

Suggesting a critical but positive understanding of these prejudices, Gadamer (1960/1999) states that prejudices - as the traditions of our own background - establish a necessary standpoint of our understandings, that is, a *horizon*.

> The horizon is the range of vision that includes everything that can be seen from a particular vantage point. Applying this to the thinking mind, we speak of narrowness of horizon, of the possible expansion of horizon, of the opening up of new horizon and so forth. (Gadamer, 1960/1999, p. 302)

Gadamer's view of the horizon is not as a limit or a narrowed vision of the phenomenon but as a field of possibilities and an open place that we can see beyond. Therefore,

> a person who has a horizon knows the relative significance of everything within this horizon, whether it is near or far, great or small. Similarly, working out the hermeneutical situation means acquiring the right horizon of inquiry for the questions evoked by the encounter with tradition. (Gadamer, 1960/1999, p. 302)

Indeed, Gadamer's notion of prejudice is that ideally the horizon is always willing to be influenced, changed and created into a new form through interactions with others, that is, *fusion of horizon*. In such fusion, my being and stories will reach another stage in understanding the world. My stories will deepen their meanings in the understanding of children's stories. And yet, I also bear in mind the fact that my stories need to be shared in a heedful manner in the research process. In other words, the research process should not interfere with, limit, or narrow down children's stories to the anticipated conclusions or presumptions of my interests. I need to know when and how to encourage and constrain my background and my story in order to help other stories to emerge.

*Interpreting (with) the awareness of social texts*

> Put your ear to the line, closer to the words. Listen. There are other texts called and recalled in the research text. The intertexuality shadows, hovers, and sometimes illuminates. (Luce-Kapler, 1997, p. 194)

Standing within my horizons, I find another facet of my story that needs to be told. In order to understand the present issues and future directions of science education, it is necessary to understand that the stories of an individual child, teacher, and classroom are also the stories of the collective minds of our society and culture. The researcher's critical mind expands the research texts to explore the social and cultural relationships that are embedded in the classroom stories.

For example, the story of the dissection class is not only my own. It is a story of the dualistic epistemology of science which has separated objectivity and subjectivity. It is a story of an ecological pedagogy which has the potential to challenge our text-oriented science teaching in contemporary classrooms. The social demands for high competitiveness in global society are intermingled in the story, pressuring teachers' practice. The story also brings forth the challenges of scientific literacy and STSE teaching for ecological and sustainable citizenship.

Understanding the underlying epistemological assumptions and ideologies of science and education will add depth and power to the research texts in imagining a trajectory for the concept of scientific literacy for the 21st century. It will challenge the taken-for-granted ideas and embedded social structures in current science curricula. These understandings of social texts will be important threads in my research interpretation.

Now, within my horizons of personal and social relationships, I am learning to listen to children's stories and understand their meanings. Without these places to stand, I would not be able to go beyond their stories to create a new story for science education.

*Interpreting (with) the openness of research texts*

Hermeneutic researchers move back and forth in the 'hermeneutic circle' as a method of interpreting and engaging research texts in the dialectical tension between part and whole (Gallagher, 1992; Smith, 1991). In this process of moving on the hermeneutic circle, the interpreters need to understand the *openness* of the circle, which contains the possibilities of future dialogues and progress of the research situations. Shaun Gallagher (1992) states,

> The hermeneutic circle, sometimes expanding, sometimes shrinking, in dialectical interplay between fore-structure and reality, between transcendence and appropriation, keeps open the possibilities that define our experience as educational experience ...Without the openness, and thereby the possibilities of recasting, revising, or reforming our preconceptions, our possibilities would reduce to an overly narrow range, and, at the extreme, experience would no longer be educational. (p. 80)

This openness expands hermeneutic understanding beyond the original texts. David Jardine (1998) emphasizes the creativity and openness of hermeneutic interpretation as a life process. Introducing Hermes as trickster and thief of stories, he suggests that the role of the hermeneutic researcher as interpreter is to create new texts out of the stories that have already been told. Once a story is taken by Hermes, the story does not hold the original text. It is interpreted, twisted, and re-created. This process is not one of controlling or transmitting the stories from one to another but of initiating and transforming another relationship through interpreting the stories. Therefore, interpretation aims not for a univocal truth to be revealed or a definitive conclusion to be reached, but rather for possible understandings of the given (the data) to reopen it to new and generative instances.

In the process of interpretation, we as researchers and interpreters echo, resonate, and incorporate the stories of children and classroom teaching with our felt experiences as the stories particularize the abstract, embody the disembodied, and connect us into the world (Abram, 1996; Geelan, 2004; van Manen, 2001). In this process of interpretation, the research texts and my horizons are integrated and developed in a grand scheme of stories.

In order to bring forth open and creative interpretation, it is important that I see myself as an active participant rather than the passive messenger of stories. I am not merely reporting or reiterating what already exists. I weave and create new meanings of life from the warp and weft of children's stories. In the process of weaving a new story, David Jardine (1998) writes, we do not know what the instance is going to be "because it is still coming... A good interpretation is... one that keeps open the possibility and the responsibility of returning, for the very next instance might demand of us that we understand anew" (p. 43).

Toward hermeneutic practice

With Gadamer's hermeneutic notion of 'horizons', I position my self in the middle of my research questions. I attempt to understand the possibilities of science teaching through children's stories and my classroom practice. With an enhanced understanding of the social embeddedness of research texts, I try to be critical toward the openness, prejudice, and creativity of my position as teacher and researcher.

When we recognize that the researcher's horizons are inescapably involved in the aspiration of hermeneutic research to reach the mutuality of inter-being and communicative interaction, the question shifts from whether or not we should avoid the researcher's subjective engagement to how the researcher can best be mindful and critical of the interactions between her horizons and the research texts. If I cannot deny my subjectivity in the hermeneutic research process and since that would not be desirable anyway, I should be attentive to its presence so that I can take meaningful and appropriate action. When the process is mindfully supported and restrained, interpretation can be more grounded and faithful to the research texts. Being mindful about the interactive dialogue between the researcher and the researched is vital to hermeneutic understanding.

To enter into discussion of the specific set of research practices that formed this specific inquiry, I will explain the details of my research questions, methods, and processes in the next chapter. The research context will also be described - children, school, and society. By describing the contexts, I will attempt to embody the meaning of my research in a particular time and place; Seoul, Korea in 2003.

# CHAPTER 7

## ENTERING AND ENGAGING IN THE RESEARCH ACTIVITIES

Introduction

This chapter explains the ways in which the research process has been formed and developed in order to reach better understandings around scientific literacy and science teaching through conversations with children. This chapter includes description of the research questions and methods in association with the research contexts - children, curriculum, school, and society. An overview of the research procedure is provided in Table 7-1.

Table 7-1. Overview and timeline of the research procedure

| **Procedure**<br>Research themes | **Time period** | **Questions** | **Methods** |
|---|---|---|---|
| **Pilot study**<br>Children's imaginings of science and technology | December, 2001 | How do children imagine their future society with advanced science and technology? | Drawing activity |
| **Dissertation research phase I**<br>Children's understandings of STSE relationships | July, 2003 | How do students understand the relationships of science, technology, society, and the environment (STSE)? | Drawing activity / Questionnaires/ Interviews |

| | | | |
|---|---|---|---|
| **Dissertation research phase II** Visions of STSE teaching | August – October, 2003 | How can ecological ways of teaching promote e relationships between scientific knowledge and students' everyday lives and promote decision making and action? | Classroom activities (e.g., discussions, concept mapping, role -playing, newspaper - making, etc.) Interviews/ Reflective writing |
| | | What are some of the challenges of STSE teaching? | Classroom activities/ Reflective writing |

Development of the research process

*The opening: Pilot study 2001*

With my interest in teaching and learning science in the context of STSE relationships, I came to question how children understand science and technology in their everyday – personal, sociocultural, and environmental – surroundings. Through understanding children's perceptions of the role and implications of science and technology in modern society, I hoped to learn how to approach STSE issues in classroom situations. Since STSE issues are value-laden and subjectively situated, it was important to know how children value and perceive science and technology in their everyday lives.

I undertook a pilot study in Seoul, Korea in 2001 to examine children's understandings of science and technology. To look closely into children's views of science and technology, I asked 108 Korean 6th graders (age 11-12) to draw a picture of how they imagine their future society, incorporating the advancement of science and technology. During this study, I attempted to discern children's expectations, interests, and concerns around science and technology. I collected the children's drawings and analyzed the contents of their drawings as well as their written explanations of what they had drawn.

After this 2001 pilot study, I became more interested in questions around children's understanding of the relationships between science, technology, society and the environment and the significance of STSE teaching. I came to question whether and how science education can help children understand STSE relationships and form balanced views. I also focused on the difficulties science educators encounter in STSE teaching that is intended to incorporate children's understandings in order to cultivate scientific knowledge within lifeworld contexts.

*The Dissertation Research 2003*

Based on the pilot study, I conducted the main research project for this dissertation in 2003. The research was undertaken with another 86 Korean 6th graders (age 11-12) at a public school in Seoul, Korea. I repeated the drawing activity at the beginning of the process and incorporated different research methods – interviews and a survey questionnaire – to examine children's understandings of STSE relationships.

In a second phase of the research, I also practiced STSE teaching in science classrooms in order to examine the possibilities and difficulties of STSE teaching in teachers' everyday practice. The expanded research questions are as follows.

*1) What are children's understandings of the roles and relationships of science, technology, society, and the environment in their everyday lives?*

*2) How can ecological ways of teaching promote the relationships between scientific knowledge and students' everyday lives, and promote responsible decision making and action?*

*3) What are the challenges of STSE teaching?*

To examine these questions, the dissertation research is divided into two parts, Phases I and II, corresponding respectively to the interview/survey data and the reflective data based on my teaching experience. Phase I focuses on the children's understandings of STSE relationships and Phase II focuses on insights gained from my STSE teaching practice. The details are as follows:

**1. Research Phase I: Children's understandings of STSE**

In Phase I, research question (1) is explored. Examining children's dialogues and stories, this section explores the various ways in which children understand science, technology, society and the environment (STSE) relationships in their everyday lives. I incorporated a drawing activity, open-ended questionnaires, and follow-up interviews. Data were interpreted and reflected upon to examine children's understandings of STSE issues and my conceptions of scientific literacy and ecological science teaching were further developed in order to plan the directions and strategies of my teaching practice in Phase II. The results of Phase I of the research project are reported and discussed in Chapter 8.

**2. Research Phase II: Visions of STSE teaching**

Research Phase II looks into the challenges of STSE teaching through research questions (2) and (3). It focuses on exploring how STSE teaching can mindfully respond to children's everyday experiences and societal interactions. To approach this question, I taught a science unit (15 lessons) in two Grade 6 classrooms. The unit, "Healthy Environment" was chosen from the Korean National Science Curriculum. No comparison or differences are made between the two classrooms in terms of lesson plans or any other classroom conditions. It is because the research focuses rather on the process of STSE teaching, not results or changes that my STSE teaching can bring. I understood a 6 week period of teaching was not enough time to discuss the result of value-laden STSE teaching. Therefore, I contemplated on the experiences and stories that children and I lived together in order to understand possibilities and challenges of STSE teaching and learning. For this reason, a comparison research under different conditions was not my research intent.

During the unit, children were engaged in various activities such as discussions, concept-mapping, role-playing, newspaper-making, poetry-writing, visiting the school garden, and a water purification experiment. From these activities, the children's work was collected for interpretation. Children's discussions and classroom situations were audio and video-taped, transcribed, interpreted, and analyzed to identify recurrent themes. Open-ended interviews and casual face-to-face discussions were also engaged in with students when opportunities presented themselves. In order to better understand the possibilities and difficulties of STSE teaching, I kept a reflective journal during the teaching practice. The journal became an important source of data to allow me to discuss a science teachers' pedagogical conflicts among oneself, children, curriculum, and the society. The results of Phase II are reported and discussed in Chapter 9.

Data collection: Mixed Methods

The use of multiple sources and methods of data collection builds up the strength (dependability, confirmability) of the research to avoid hasty readings and misunderstandings of the research 'texts' (Geelan, 2004; Lincoln & Guba, 1985). That is, we approach the research questions with different methods in different situations so that the data can be collected from diverse resource pools and our understanding of the multivalent meanings of the data can be saturated. Multiple methods allow the data to be interpreted with attention to its coherence and awareness of its contingencies.

I employed multiple approaches to the research questions and multiple forms of data collection in order to strengthen my interpretations of the data. I utilized several methods such as a drawing activity, interviews and questionnaires to construe children's understandings of science, technology, society, and the environment (STSE) relationships. Classroom conversations and children's reflective writings also provided evidence that helped me to understand the trajectory of students' STSE understandings.

To reinforce the meaning of the research texts, I also engaged in peer discussions and debriefing (Lincoln & Guba, 1985). The raw research data and my tentative interpretations were shared with friends and colleagues in Korea as well as Canada through verbal interactions or via email during and after the data collection. The complementarity of those different methods broadened the base of the data resources available for my interpretations and supported the strategic reliability of the research data collection.

The research methods and strategies are explained in detail in the following sections.

*Using children's drawings*

Children's drawings can provide a means to project their imaginary ideas into a medium of visual communication and representation. Seen as the interplay of thoughts, images, and graphic elements, children's drawings reflect their thinking and interactions with/in their own as well as outer worlds (Cox, 2005; Kress & van Leeuwen, 1996; Matthews, 2003). This process of sign-making is also part of children's interpretation of their society and culture (Cox, 2005; Mathews, 2003). That is, children's drawings are contextual and embodied actions arising from and existing as part of their experience (Cox, 2005; Mathews, 2003).

Using drawings is an efficient way to comprehend children's experiences, thoughts, and feelings and, therefore, an effective way to approach research questions (Ring, 2001). However, there have been on-going debates about the validity and reliability of people's interpretation of children's drawings from psychological and psychoanalytical perspectives (Mathews; 2003; Ring, 2001). Given an understanding of these conflicting assumptions, I did not use the children's drawings as my sole method to interpret their understandings of science and technology. In my research, drawing was used not as a means of semiotic or psychoanalytic interpretation of children's thoughts but as a tool to open up contextual conversations with children. It was a welcoming and comfortable way for us to get into the topic.

Children were asked to draw a picture on a specified theme and also to write a brief explanation about their drawing. In my verbal and written instructions for the drawing, several comments were made to reduce the pressure on students who felt insecure about their artistic skills, techniques, or about assessment and consequences. I encouraged children to express their own thoughts and feelings on the topics without much interruption. The following is the written instructions given to children at the beginning of the activity:

***Drawing/Writing activity***

Draw a picture of your imagination of the future with science and technology.

*What would our future society look like with the development of science and technology?*

Let's imagine it and draw a picture of your imaginations.

Remember that...

- It is not a drawing class so you don't need to worry about your drawing skills, choosing colors or designing. You can use pencils. No need for colors.
- Please write a short explanation about what you draw on the back of the paper.
- Try not to draw what you can see/have seen in science fictions books or movies. Take your time and think about what would be possible to happen in your future. It is important to express your own thinking on your drawing.
- You can choose one theme to draw or various themes like mosaics. You can draw in whatever way that you feel most comfortable with.

After the drawings and their commentaries had been completed, the students were invited to participate in small group interviews about their drawings and their written explanations, with these artifacts in front of them. We shared drawings and made comments on each others' drawings. The conversation was expanded into a discussion on how we experience and understand the issues around science and technology in our society. This interactive mode of drawing – and conversations stimulated by drawing – helped us to discuss the intentions, meanings, and themes of the students' drawings. In this way, the process was not about the children as sign-makers, and the researcher as a separated viewer or interpreter, but about dialogical communications through face-to-face interactions.

*Questionnaires*

The use of questionnaire data in this project was intended to gain a general overview of children's ideas on STSE relationships. It was intended to avoid over-interpretation and over-reliance on individual opinions and experiences. Among children's understandings of STSE relationships, questions in this section were intended to examine the relationships between science and everyday life, science and society, and science and the environment. Children's answers were taken into consideration to assist in the interpretation of the other data in the study and the development of themes in relation to children's understanding and today's world of science and technology. The questionnaire was open-ended and included the following questions (refer to Appendix A for the results):

***Question 1: Science and my everyday life***

- How do I experience science? Is my everyday life related to science?
If so, in what way? If not, why?

***Question 2: Science and Korean society/nation***

-Do you think the development of science is necessary for our society and nation?
If so, why? If not, why?

***Question 3: Science and the environment***

-I think the development of science influences the environment because….
-I think it does not have much relationship between the two because….

*Interviews with children*

After completing the drawing activity and the questionnaires, children were invited to participate in voluntary interviews. Interviews and discussions were carried out with five different groups of 5-8 students for 30-50 minutes each. Among these groups, there was one focus-group of 8 students whom I interviewed several times throughout the research and other 4 groups were talked to only once.

Even though the interviews were open-ended and informally structured, I aimed to focus on the topic of STSE relationships by suggesting topic-related questions and comments. I used children's work such as drawings and poems to commence the interviews. For example, interviews started with a simple question about their work such as "what are these little computer chips doing on your drawing?" or "what line do you like the most in your poem on trees?" Then the interviews were gradually developed to discuss children's everyday life experiences with science and technology.

Max van Manen (2001) explains that even though interview is commonly practiced in educational research, it is difficult in interviews to approach the essential moment of "inter-dialoguing." van Manen states that in this moment, the interviews are oriented to the originally intended research questions and topics. Thoughtful preparations are needed before and in between interview schedules to avoid confusion and the overflow of ideas. Also, there are mutual understandings in relation to topics, and empathies between the interviewer and the interviewees, that need to be approached during the interview. Max van Manen explains that the space of inter-view is the inter-relational dimension – that something comes into view between the interviewer and the interviewees and among interviewees themselves. Therefore, the interviewer needs to interactively and mindfully listen and participate in the interview. Each moment of the interview process – entering, dialoguing, and closing – needs the researchers' heedfulness. When comfort and rapport are created, openness comes into play and a genuine conversation can be developed. During the interviews and conversations, I strove to be mindful of my actions such as eye-contact, gestures, and making comments to encourage children's participation with trust, comfort, and willingness. I tried to make our space as comfortable and open as possible so that the interviewees would not feel reluctant to share their opinions with one another.

All of the interviews were carried out in Korean and transcribed and translated into English for data analysis (see Appendix B for an example). The data were coded and selected according to similarities and differences. Through moving back and forth through the selected data, the data were interpreted, reflected upon, and thematized to reach a set of stable meanings drawn from the data.

*Reflective journal writing*

During the conversations and teaching with children, I often found myself in the middle of questions about who I was as researcher and what my struggles in classroom teaching meant in the scheme of science education. Through writing my reflective journal, I tried to understand the meanings of these questions and struggles. The process of reflection provided me with self-awareness and tools to examine my being as a teacher and researcher. It encouraged me to project new visions and participate in developing the research texts.

Max van Manen (2001) explains that thorough interpretation and reflection can lead the researcher into active practice and a deeper appreciation of the implications of one's research. He states:

> Reflection deepens thought and therefore radicalizes thinking and the acting that flows from it. All serious and original thinking is ultimately revolutionary – revolutionary in a broader than political sense. And so to become more thoughtfully or attentively aware of aspects of human life which hitherto were merely glossed over or taken for granted will more likely bring us to the edge of speaking up, speaking out, or decisively acting in social situations that ask for such action. (p. 154)

I strove to capture reflective and reflexive moments in my journal throughout the research. Journal entries were reflected upon again later in association with the data. Email communications with friends were also an important part of the reflective process in my research. The emails were re-visited after the research and reflected on once again. The reflective journal became a powerful source to expand a discussion on STSE teacher's identity formation.

The final section of this chapter addresses some facets of the contexts within which my teaching experience occurred, including the Korean national science curriculum.

<u>The contexts of the researched</u>

To enrich the thoughtfulness informing data interpretation, it is important to understand the horizons of both the researcher and the researched. I explored my own horizons as researcher in the previous chapter. In this section, I will describe what I understand to be the horizons of the researched - the time and place of children, school, curriculum, and society.

Since the research was conducted at a public elementary school in Seoul, Korea, it is crucial to take into account the Korean education system, the societal situation, and the ways in which children's lives related to these contexts. In this way, the research texts can be contextualized within the particular time and place – Seoul Korea in 2003 – so that its interpretation and reflections can be embodied and better understood in the context.

*The National Science Curriculum*

There is one single mandatory national curriculum in the Korean public education system. Because I conducted my research within the context of the national science curriculum, this section includes a brief background of Korean national curriculum development and STSE curriculum.

The initiation of curriculum development began after the Korean independence from Japan in 1945. During the pre-curriculum period (1946-1952), educational foundations were offered by the US Military Government Office in the Education and Management Department (refer to Appendix C for the overview of national curriculum developments and changes). Since this start, there have been seven waves of curriculum reform over the past 50 years. Curriculum development in the responsibility of the Korean Education Development Institute (KEDI) in the Korean Ministry of Education and Human Resources. Curriculum development has been influenced by various educational theories and models adapted from western countries and transformed into the Korean context. The influence from the United States has been dominant in the Korean curriculum development according to the Ministry of Education and Human Resource (1999). In this curriculum development framework, science curriculum has also been developed with the western contexts of science education. In the process of curriculum reform, curriculum developers and educators have tried to keep the balance between traditional Korean values and the changes in the new era.

Elementary schools have been implementing the 7th National curriculum since 2000. The catch slogan for the 7th science curriculum is to "prepare collaborative and competent global citizens with new knowledge and skills of science and technology for globalization and information era in the 21st century" (The Ministry of Education and the Human Resource, 1999, p. 100). The guiding rationales of the curriculum are:

(1) student-centered education; self-initiating/leading learning,
(2) preparation for globalization and information era,
(3) contemplation on appropriate learning, i.e., appropriateness of quality rather than quantity, and
(4) emphasis on classroom- and school-based autonomy of curriculum.

Science-Technology-Society-the Environment (STSE) elements have been included since the 5th National Curriculum in 1987 in the national science curriculum. Since the movement of STS was adapted from science curricula in the United States, its rationale and process have been unrecognized by science researchers and teachers. Nor have there been enough studies on the implementation and effectiveness of STSE curriculum in the Korean contexts (The Ministry of Education and Human Resources, 1999). One suspects that STS(E) curriculum is seen as an add-on or forgotten part of science education – something that is also seen in other countries.

*The school*

The school where the research took place is located in a residential area in Seoul. The community consists of high rise apartment complexes, condominiums, and townhouses. Two pictures of the neighborhood are included (see Figure 7-1 below). Children live in the kinds of apartments or townhouses seen in the pictures. Their everyday environment is very modern, technologically advanced, and crowded. This is common scenery in the city of Seoul, which has high population density[11]. It is worth paying attention to these pictures to understand the environmental context within which the stories from children arose and the classroom teaching on ecosystems and the environment occurred.

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[11] The population in Seoul is about 11 million people in 605.52 $km^2$. Compare this with the population of the province of Alberta; about 2,974,807 people (Resource from 2001 census, Canada statistics, available at http://www.gov.ab.ca/home/Index.cfm? Page=2) live in Alberta; the size of land and freshwater areas totals 642,317 $km^2$ (Resource from Natural Resource, Canada, 2001, available at http://atlas.gc.ca/site/english/facts/surfareas.html), which is much bigger than the whole land area of South Korea. This yields a population density for Seoul of over 18,000 people per square kilometer, compared to a population density for the city of Edmonton of just under 100 people per square kilometer.

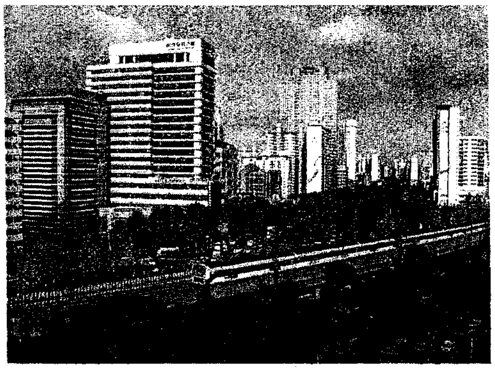
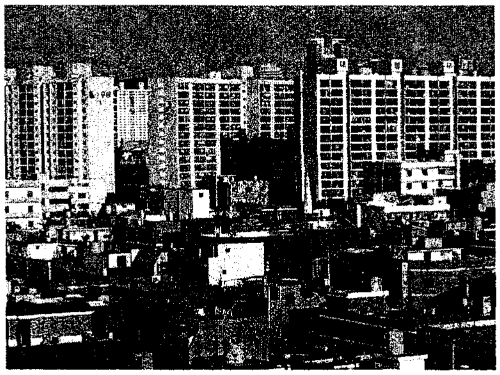
 

Figure 7-1. The neighborhood of the school

The school has 47 classes; 7-8 classes in each grade. Each class has about 45 students. Students usually study in their own classrooms but also have access to several extra classrooms such as a music room, gym, science lab, computer lab, school library, etc. Each classroom is equipped with audiovisual facilities; TV, VCR, and stereo systems. A computer with high speed internet connection is also provided and located near the teacher's desk.

*The participants*

Eighty six sixth graders (age 11-12) from two classes participated in the dissertation research. There were 44 boys and 42 girls. They participated in the research for four months from July 2003 to October 2003. The socio-economic level of the children's homes is middle-class and relatively stable according to the classroom teachers. The teachers said most students were well-prepared and supported by their parents in terms of school supplies and resources, internet access, homework aid, and so forth.

The school subjects for Grade 6 students are Moral Education, Korean, Social Studies, Mathematics, Science, English, Music, Physical Education, Fine Arts, and Home Management. There are also extracurricular activities that students need to attend once a week such as dancing, tennis, calligraphy or reading. These activities are part of mandatory school curriculum. There are 3 science classes each week and class duration is 40 minutes per each class. This is flexible and can be modified by teachers, however, they need to meet a requirement of a total of 102 science classes over the school year (the Ministry of Education and Human Resources Development, 1999). My teaching followed the regular classroom times, that is, three 40 minute classes a week.

More than 90% of the participants attended extra courses at private institutes to learn computer skills, musical instruments, martial arts, English conversation, and other extension studies. Some students attend more than one course a week. Some students take those courses for their own interest but many of them said that they were sent to the cramming schools by their parents. From the parents' perspective, those extra courses would assist their children to get better scores or techniques that would eventually help them enter 'good universities'. For them, preparation for the university entrance exam has to be started at this early age. The public as well as private education system has been operating in this competitive mode for a long time since the university entrance exam is a harsh reality in the Korean education system. It challenges many educators' devotion to meaningful childhood and the importance of human values through education. The demands from parents and society often challenge teachers' pedagogical enthusiasm and ethical calling in those issues.

*The society*

The summer in year 2003 was a unique time for Korean society. After North Korea officially declared their possession of nuclear weapons in the spring of 2003, the whole Korean peninsula and international society were stirred up with the impending tensions of inter/national security and global power relations.

This societal issue was reflected in children's stories of science, technology, and society, thus, thoughtful attention to the dynamics of this notion were necessary in interpreting the data. Therefore, I will explain the social situations in detail in with the context of reporting and discussing the research findings.

Based on these contextual factors of the researched, Chapters 8 and 9 share the research findings and analysis. The situatedness of the research work in the contexts of children, curriculum, and society provides the ground for discussing the visions of scientific literacy and STSE teaching that existed in the Seoul classrooms that are the focus of this study.

# V

## RESEARCH FINDINGS & REFLECTION

This section reports the data from the study with interpretation and reflection. Through sharing Korean children's stories and conversations about science, technology, society, and the environment, I discuss the issues and visions of scientific literacy in a contemporary society in Chapter 8. In order to explore the possibilities of scientific literacy and STSE curriculum, the research engages the researcher's teaching practice. Reflections on challenges of teaching scientific knowledge as connected life knowledge (Chapter 9) and teachers' pedagogical dilemmas in relation to STSE teaching (Chapter 10) will be discussed.

# CHAPTER 8

## CONVERSATIONS WITH CHILDREN ABOUT SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT

### Introduction

In the same way that we as adults have constructed certain understandings of science and technology through our experiences of the natural world, science in classrooms and sociocultural relationships, children also learn and construct their ideas of science and technology through their own experiences. That is to say, their understandings of science and technology are not only in the domain of school science but also of society *per se*. In this regard, in order to discuss children's visions of scientific literacy, it is important to question the ways in which science has been projected in modern society and understood in our and children's minds.

Since the goals and means of science and technology are embedded in social schema, the public learn, adapt, and perform science and technology based on taken-for-granted schemata. Education also becomes part of the social system and accommodates its goals. For example, in the early 1990s, Korean society was enthusiastic about cutting edge science and technology such as biotechnology. The public was encouraged by the idea that innovative science and technology would be the solution to economic growth and to human problems such as food shortages and incurable diseases. The excitement and desire for a new future infused with science and technology were rigorously introduced in school science to encourage students to get into science. Students were actively adopting the dramatic ideas and changes of the scientific and technological revolution with eagerness and confidence for the future. I, as a teacher, also conducted activities to introduce science in terms of our most idealistic views about development, and taught students about the substantial prospects of scientific knowledge for the coming era. Science was indeed viewed as being the future of our society.

Thinking about the enthusiastic projections in the past, I ponder the changes we have faced through scientific and technological innovation and the ways in which we have been confidently dwelling in the nexus of those changes in today's world. I also wonder how my teaching would be different if it better reflected the issues and concerns with science and technology in modern society.

With these understandings, I have come to realize that the discussion of scientific literacy needs to include an understanding of the sociocultural projections of science and technology in order to examine the goals of science education in contemporary society.

In order to begin the development of such an understanding, this chapter explores Korean schoolchildren's understandings of science, technology, society, and the environment through their everyday experiences. Through exploring children's stories, I question how (and whether) science education, in terms of contemporary visions of scientific literacy, takes into account their understandings. This chapter incorporates data from both the pilot study and dissertation research Phase I, since they look at the same research questions. The findings from this part will be a substantial asset that will support my quest to embody STSE teaching in the context of children's stories in the classroom science teaching that comprises Phase II of the research project.

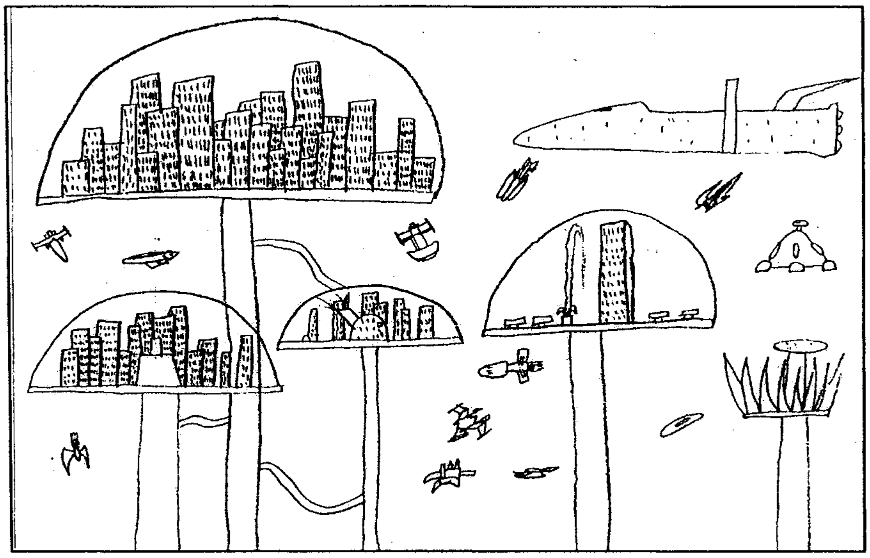
## Children's understandings of STSE relationships

### *Utopian expectation and anxious relationship*

To examine children's understandings of modern science and technology, I conducted a drawing activity with 108 Korean 6$^{th}$ graders (age 11-12) in my pilot study in 2001 and another 86 Korean 6$^{th}$ graders (age 11-12) in the dissertation research in 2003. This drawing activity was a modified version of the "science drawing contest" which annually took place at Korean public schools in the 1990s to elevate students' interests in science. During the drawing activity, children were asked to draw their imaginings of science and technology in their future worlds and wrote a short explanation about their drawings.

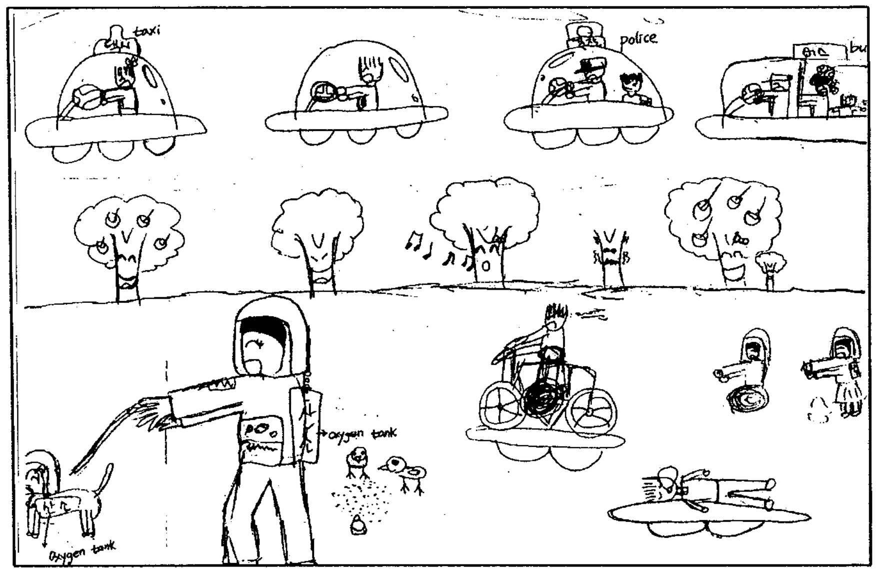
The majority of children in the studies envisioned science and technology as having unlimited capacities of solving human problems such as overpopulation, energy shortage, incurable diseases, environmental degradation, and so forth (see Table 8-1). Science and technology has taken the position of problem-solver and life-developer often based on utopian and science fiction solutions and devices in children's understandings. Separating ourselves from the world that we live in, their solutions are seeking for another place in space or undersea as possible solutions to overpopulation and pollution (see Figure 8-1). To overcome severe diseases, human body parts could be cloned and replaced. Computerization would make living conditions more desirable, convenient, but dependent. The utopian expectations and excitement of science and technology underlie in children's imagination (see Appendix D for more drawings).

Figure 8-1: Examples of children's drawings



Hansoo: I drew a city built on the sky. There would be no land left for us to live in the future because of overpopulations and environmental destructions so we might need to build a city on the sky with advanced science and technology (Boy, age 12).


Junsuk: I came up with the idea of cloning. We could clone earths and move to another earth when our lives would be in danger in the future world. Or move to another planet. We would be able to move to another planet with the development of science and technology (Boy, age 11).




Cojin: People would need to carry oxygen tanks to breathe safely. The future environment would have more air pollution. Science and technology will help us to solve the problems. I can walk my dog by getting him an oxygen tank too (Girl, age 11).

In interpreting these drawings, the notion of futuristic visions do not seem to be much different from Korean children's views in mid 1990s, when I was teaching. However, from children's understandings in this study, I realize that there is children's concern about insecurity around science and technology. Some of children's drawings indicate that modern science and technology is no longer only a hopeful fantasy, but it has also resulted in anxiety about relationships to the human life world. In their drawings, children expressed their concerns about wars, technological violence, inhumanity, and environmental destruction in local and global societies (see Table 8-1).

While some drawings directly express specific concerns such as technological armaments and wars, some are rather subtle and indirect. For example, Hansoo' and Cojin's drawings above articulate hopes and optimism in scientific and technological solutions, but there are also their concerns about environmental destruction lurking behind their optimistic visions.

To some extent, children's ideas summarized in the table 8-1 represent public understandings of science and technology in Korean society. Children's imagination of science and technology is not their own creation, but rather the (re)presentations of what the society *per se* has been projecting as science and technology through mass media, books, magazines, exhibitions, and internet networks (Driver et al., 1996; Mander, 1996). Through those projections, children have embraced positive, ultimate, and omnipotent worlds of science and technology in the advent of techno-scientific culture of today's world (Mander, 1996). "Indeed, science [and technology] has grown and spread around the world as a characteristic *subculture* of the general culture of *modernity*" (Ziman, 2000, p. 25, Italics original).

Table 8-1. The content of children's drawings on "How do I imagine future society's relationships with science and technology?" (Total N = 120)

| **Contents** | **Number** | % |
|---|---|---|
| Space science (spaceship, space traveling, living in another planet) | 26 | 21.7 |
| Robots | 16 | 13.3 |
| Flying vehicles | 16 | 13.3 |
| Computerized home/work environment | 15 | 12.5 |
| cities in the sky level | 10 | 8.3 |
| Cities under the sea (submarines, living under the water) | 7 | 5.8 |
| Better Energy resources (solar energy, recycling/alternative energy) | 4 | 3.3 |
| Cloning | 3 | 2.5 |
| Pollution eliminating machine | 2 | 1.7 |
| Violence (war, armament, crimes, traffic accidents) | 10 | 8.3 |
| Pollution/Environmental destruction (air pollution, waste) | 5 | 4.2 |
| Vanishing humanity/laziness | 2 | 1.7 |
| Destroyed earth | 1 | 0.8 |
| N/A | 3 | 2.5 |

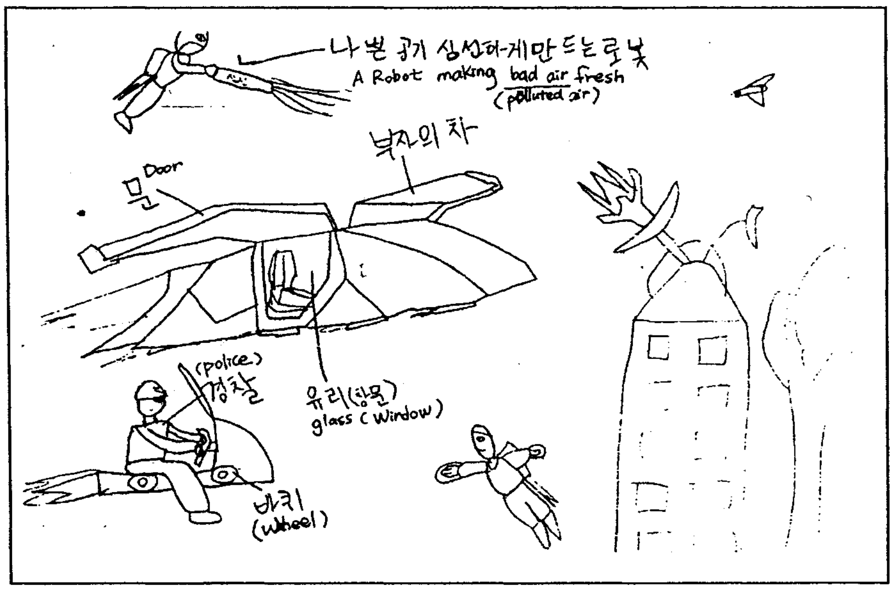
John Ziman (1980, 2000) remarks that scientism has been a key factor in western philosophical and political manifestations since the rise of modern science in the 17th century. The "know-how" of scientific applications resulted in the idea that science is ever progressing towards a complete and comprehensive scientific and technological world and constituting the ultimate reality of our living (Barrett, 1978;

Keller, 1993; Ziman, 2000). However, with the optimistic understandings, we also experience uneasiness, unsettlement, and insecurity of dramatic revolution of science and technology which demands us to restructure our minds, ethics, and environmental and socioeconomic values in modern human relationships (Nandy, 1988; Shiva, 1993). Robert McGinn (1991) points out,

> Developments in science and technology have engendered disturbing new feelings in modern Western culture. Apprehensiveness over the fragility of peace, fear of the carnage of nuclear war and more recently anxiety over environmental degradation now seem ongoing and sufficiently wide spread to quality as characteristic of contemporary Western culture. (p. 135)

Regardless the disturbance and anxiety of undesirable outcomes of science and technology, the dominance of scientific and technological innovations prevails in modern culture and has become the characteristics of contemporary civilization. Errol Harris (2000) writes that "we tend to equate science with civilization itself, considering peoples who lack it, or are scientifically unsophisticated as, to that extent, uncivilized, and those who enjoy its advantage as the most advanced" (p.3). In this respect, science and technology have become another symbolic idiom of social structure locally and globally. This notion was also shared and articulated by children during the study. For example, a student explained his understandings of the complexity of science, technology, and socioeconomic relationships in his drawing (see Figure 8-2).

Figure 8-2. Technology in the future




Hyun : There would be robots developed to treat air pollution. The car in the middle is a rich man's car. (Boy, age 12)

In the middle of his drawing, Hyun drew a flying car and explained it was a rich man's car. He explained that science and technology is only for people who have money to afford it. Thereby, the development of new science and technology does not help the poor and the powerless to have better lives. In a follow-up conversation, Hyun asked, *"Why are children starving to death in Africa? People said science and technology would solve the food shortage in Africa but in fact, many children are still* *starving to death. With the development of science and technology, the gap between the rich and the poor is getting bigger."*

Relating science/technology to social conscience and equality was expressed by other students during interviews and classroom discussions. Children also explained that rich people would have better technological equipment to protect themselves from pollution or any other disasters. Some children also agreed that only certain people would benefit from cloning for medical treatment which would not be accessible for every one in the society. Through these views, I began to realize that some children understand critically the notion of science and technology in relation to social phenomena. I was impressed by how articulate their opinions were through their stories and discussions. Their awareness of STSE issues have already started burgeoning and await our attention.

In today's world, children have been experiencing both their own desire for utopian future of science but are aware of possible consequences. This raises a question of how these utopian projections and anxious understandings would influence children's future decision making and their taking action as citizens. How is science education to respond? Such ambivalent notions expressed by children are subtle and unidentifiable and thus have been largely neglected in the agenda of science education. Some science educators might argue it is not a domain of science education. And yet, in the discussion of scientific literacy and the direction of science and technology in future society, students' utopian and anxious understandings need to be openly shared and discussed to become critical and confident decision makers and action in the complexity of modern science and technology.

*Local STSE Stories in global contexts*

While I understand children's stories of utopian beliefs and anxieties about science and technology as being socially and culturally constructed ideas over time, I also noticed that their understandings seemed to reflect current social issues. For example, children's stories included the North Korean nuclear weapons standoff in 2003. The following table indicates my reflections on the left side along with the news headlines from one of Korean daily newspapers in English language, *The Korea Herald*[12] on the right column. Such a summary provides a glimpse of the impending

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[12] *The Korea Herald* is a daily newspaper in English in Korea. Since 1953 it has been one of main information resources about Korean politics, business, education, and culture for foreign people in Korea as well as other countries.

issues around North Korean nuclear weapon standoff and the tensions around international relations in Korean society.

***Seoul, Korea in Summer 2003***

'War' is not a strange term in the Korean society now. Since the war in Iraq and North Korea's Nuclear weapon standoff, the word, war became very close to Korean people. The tension between North and South Korea has been elevated and it has also resulted in the complexity of international relations and interests. With the impending issues, the public started to think of the possibility of war in the Korean peninsula even though the chances seem still low to some people.

In the meantime, anti-American movement became intensely ignited again after the deaths of two junior high school students caused by a US army truck in 2001. The public has demanded the Korean government to take on follow-up actions and charges toward the US military and the soldiers, however, there have been no satisfactory outcomes and it provoked people's anger and distrust toward the government. The love-hate relationships between Korea and the US has been always challenging in the nation's sovereignty and foreign affairs. With these dynamics, the government has been positioned in between the public opposition and the US influence around national and international issues.

**News headlines related to North Korean Nuclear weapon issues in July 2003, *The Korea Herald***

Seoul urges N.K. (North Korea), U.S. to make mutual concessions (07/01)
Kim Jong-il (the leader of North Korea) admitted having nukes (07/04)
Even with troop relocation, U.S. can deter North Korea / N.K. nuclear issue to top summit agenda (07/07)
Roh, Hu (The leaders of South Korea and China) use ambiguity to avoid provoking N.K. (07/09) Koreas indicate nuclear issue will top agenda in high-level talks (07/10)
N.K. finished reprocessing (07/14)
North Korea nuclear reactor project at crossroads (07/16)
Two Koreas' border guards exchange fire (07/18)
N.K. deploys more Rodong missiles (07/19)
Roh, Bush optimistic on N.K. nuclear talks (07/26)
CNN airs special reports on Korea all this week (07/28)
Roh urges N.K. to abandon nukes

Living with these impending tensions, people go on with their everyday routines and kids are coming to school to study.

(07/28)
(Available at *www.joins.com*)

While the mass media reported the tension of nuclear weapons and international talks as headline news every day, the public understood the tension and conflicts around the issues and expressed their own opinions in terms of national sovereignty and international interference. The South Korean government struggled to alleviate the tension and conflicts among the Korean public, North Korea, and international power relationships. The whole society seemed to be under the pressure and tension. In those everyday conversations, children were with their families at the dinner table, in front of TV, and on the corner of street. They heard, wondered, and constructed their own understandings about these issues.

When children were asked to draw and explain the relationships between science and technology in the future society, the nuclear weapons issues were expressed in many of their understandings on science and technology (n=6 out of 86 students). Children elaborated the conflicting ideas of science, technology, war, peace, and inter/national security in this troubled time (n=13 out of 86 students). With those drawings, open-ended interviews were conducted with children. The following example provides an illustration. This is an excerpt from an interview with a group of children on July 22nd, 2003. On the right side, I include a news article from *the Jungang Daily*[13] newspaper.

**Interview with children on July 22, 2003**

Mijung: Why did you make connections between science and wars?

J: We can't really make missiles, jet engines and so on without science.

.....

Mijung: I have seen many of your drawings with wars. Why did war become an issue for your guys?

D: It is because there was a war between the US and Iraq and we have been hearing about it a lot these days.

J: For the development of science or some other stuff, people would need oil and Iraq has it so...

E: There is also a nuclear weapon issue with North Korea. We hear it every day.

...

Mijung: Then can we view that science is necessarily dangerous or negative? What makes science dangerous?

J, B, T: It is we people who have cruel minds. Ya, I think so. I agree...

**A news article**

Fuel-rod treatment is claimed

(July 14/2003, *The Joongang Daily)*

WASHINGTON — North Korea has told Washington that it has finished reprocessing 8,000 spent fuel rods to extract plutonium for nuclear arms, a former Millennium Democratic official said yesterday, quoting a U.S. diplomatic source... According to nuclear experts, if the North has finished the reprocessing, it would be able to produce 28 to 35 kilograms (61 to 77 pounds) of plutonium from them, enough to make four to seven nuclear warheads. The North is believed already to possess 10 to 12 kilograms of plutonium... The United States

[13] *Jungang Daily* newspaper is one of the major newspapers in Korea. A poll shows that about a quarter of newspaper readers choose *Jungang* newspaper (available at http://211.233.22.196/news/ article_info _print.asp?no=661). It serves in both Korean and English.

D: We should do science with self-realization.
J: We should know science and technology right.
Mijung: Could your explain more on that? What is the right way to know?
J: I mean that there are some negative things in science and technology that we should know of.
D: I think we need to know science and technology can destroy our lives when it is used in wrong ways, so…I mean we should awaken ourselves to that point.

and several other countries discussed ways to tackle the trade in nuclear, chemical and biological weapons by forcibly intercepting shipments of the arms.
By Kim, C.
(Available at *www.joins.com*)

Children seem to appreciate the implications of science and technology in current international conflicts. Considering the war in Iraq and the current social issues in the Korean peninsula, the violent images of war, the means of science and technology, and the destroyed human lives were linked in children's minds. Among those images, they hoped for the revival of humanity through sensibility and mindfulness of our decision making. Children suggested that we need to develop and practice science in ethically *right* ways and this self-realization of humanity would be a key to responding to the dangerous implications of science and technology.

Despite their awareness of the dangerous implications of nuclear weapons, children expressed ambivalence and hesitation in their decision making on the dis/armament of nuclear weapons when Korean nation's security was involved.

Children agreed that nuclear armaments would promote the nation's security and sovereignty. For them, security seemed the first and foremost matter for Korea and the people in this time of conflict and nuclear arms seemed to be the strongest means of defence. The following conversation shares children's ideas confronted with the ambivalence about nuclear weapons.

**Interview with children on July 22, 2003**

D: If every nation had nuclear bombs and if the US or any other country wanted to start a war, then they would know it would turn to be a nuclear war and they would also get a lot of damages in themselves. So it [the fact that each county has nuclear bomb] could prevent all of us from a war.

E: I agree to make a nuclear bomb because it can prove that our capacity of science and technology excels and our nation is strong. It should not go beyond that. Using it in wars will cause many innocent people's deaths with no reason. However, if every nation has nuclear weapons, then it will be difficult to start a war, nobody could threaten others with nuclear bombs.

K: I agree to make nuclear bomb too, but I hope it is not used for wars. When dynamite was invented by Nobel, it was used for mining but it was also used in wars to kill people and became hatred. So maybe it is only a hope… but…. nuclear power can be used only for the nation's development.

J: Ummm… even though people try to use it for only nation's development, the result would be the same. I

**A news article**

No time for nuclear blame game

(July 16/2003, *The Joongang Daily)*

…Therefore, nuclear experts called it a "red line" which the North should not cross, and they have been working hard on countermeasures if Pyeongyang went ahead. Still, the Korean people prefer not to think about the worst situation they can imagine; that the South could not deal with North Korean nuclear threat on its own and that a war on the peninsula, even if it is not nuclear but a conventional one, would bring mean, because every nation would be tempted to go for war for their profits, then many people would get hurt because of that. And its impacts will continue from generations to generations. So I think we should just get rid of all the nuclear things in the world and start conversation to remove the grudged hatred. But adults have different opinions…to make the nation strong…which I don't really understand….

K: To make nuclear bombs, science and technology involved are very great…but even though it is very good science and technology and when it is used in a wrong direction, it has no meaning.

A: When I think about those things, I feel really frustrated. When one country is strong, the country uses its strength to threaten others. But what's the meaning of it? When they want to show that they are stronger than any others, then they can achieve their reputation for helping other nations. But why only things like a nuclear bomb should be the way? ….

D: Only the US and a few other countries have nuclear weapons. The US is the strongest nation. Is that right? (He paused and looked at me. I only smiled and said "keep going.") Anyway, if Korea were in the same situation, we would like to live better than other nations too. So the US now uses their power to be better than any other countries and made nuclear bombs and…but it is not fair that they don't let any other countries have it when they have it. Anyway, the strong nation could do anything for their greed and benefits.

….

J: But…even though, like the US, people say they love peace and they have a lot of money and oil and everything, but they still want to deprive more things from others. So if we think about that case, science is

unimaginable devastation to the South.
The sense of self-pity that few if any solutions can be mustered by our own hands, coupled with the vague expectation that the international community, including the United States, will intervene at an appropriate stage seems to be feeding our sense of tranquility.
by Kil, J.
(Available at *www.joins.com*)

Doomsday Clock

With growing concerns about impending crisis of Nuclear wars and other terrors, Doomsday Clock was created in 1947. The clock has moved its hand to midnight whenever there is a significant increase of threat in world peace. Now since 2002 with September 11, several other terrorist attacks, failure of disarmaments, etc., its hand shows seven minutes to midnight (Available at: *www.thebulletin.org*).

used in dangerous ways more than peaceful ways.

.....

In the children's conversation, we see both their frustration with the dangers of nuclear weapons conflicting with patriotic loyalty. As a means of protection, the children seem to conclude that we need more science and technology for security, economic development, and power to survive through this difficult time as expressed by D. *"Anyway, I think, because the North [Korea] has nuclear weapons, the US cannot easily invade Korea."*

Following this interview with the children, I thought about the public discussions on the Korean sociopolitical situations in international communities. Korean feels vulnerable as a nation. After the Korean independence from Japan in 1945, following the Korean War in 1950-1953, and after the IMF crisis in 1998, Korea has experienced complex international conflicts in terms of global economy and political power relationships. Many of us have lived though these times to witness how Korea has built up the nation's democracy and sovereignty. As I listened to children's opinions, I thought about this frustration and the concerns about the future of Korea as well as the sustainability of the world. Their stories resonate with this struggle.

Indeed, children reflect relationships, and visions of the future in today's world. Their stories are not only based on the situations of the local community but hermeneutically can be expanded and shared as the stories of global society. These conversations with children cast a fresh light on the relationships of STSE issues in our shared future. They encourage a consideration of how science and technology should be practiced under the pressure of the global competition and countries' struggles for their own security and sovereignty. In this context, what would the meanings of scientific literacy and how do we envision science education in our time?

I think about the slogan of science education for the new century; "to prepare students to become capable world citizens for globalization and information era in the 21st century." Having been embedded in the dream of science and technology under industrial competitiveness and commercialized culture (Pinar, 2004; Smith, 2002), I feel that as a science educator I have long been blind to the wider global economic and security issues as these related to science and society. In narrowly technologized models of education, these issues are ignored. Reflecting on these, I wonder if I might have refused to acknowledge those issues so that I could avoid the burden of knowing. Because once I acknowledge that I *know* it, then the responsibility of knowing will come into my being. As Lacanian psychoanalysis introduces (Carson, 1997; Felman; 1987), my ignorance might have been my active resistance to knowledge. However, I can no longer ignore it because it has come into my consciousness through my reflection on personal journey, through the epistemological questions of science, and now more significantly through children's stories.

We commonly regard children as *future* citizens who *will* get involved in future society. However, these conversations show that children are already within our time and place constructing their own ways of understanding science and technology. Educators need to remember that children have always been with us and will continuously be. We are often ignorant to children's awareness, presence, and participation in our public dialogues. This ignorance will miss out useful opportunities to develop students' critical thinking skills in accordance with current STSE issues. Especially, in a precarious global time, issues of science, technology, society, and the environment need thoughtful examination and reflection in local community bases. It is teachers' mindful teaching that can bring up children's ideas to grow into mature, sound, and critical understandings to become capable world citizens in scientific and technological matters. By doing so, I also learn to dwell myself in the harmony of teaching and living in the context of modern science and technology with children.

*The Paradox of "development": The dichotomies of economy and the environment*

Lastly, another aspect that I like to underscore in children's STSE understandings concerns their relationship with the environment. With increasing concerns about environmental destruction in children's drawings, I became interested in children's understandings of science and technology in relation to environmental issues. This topic is again taken up to in my teaching on ecosystems and the environment in the next phase of the research.

In this study, the majority of children expressed contradictory understandings between socioeconomic development and environmental destructions attributed to science and technology. For example, a student described how science and technology was destroying the natural environment in certain areas while developing the nation.

> There are...huge problems like Sae-Man- Keum Project... It is a landfill project on the West coast to get more land. It destroyed the ocean ecosystems around that area...I think science and the environment have very close relationships. (Girl, age 12)

Eighty seven per cent of children (n=75 out of 86) answered in the questionnaire survey that the development of science and technology causes harmful impacts on the natural environment whereas ninety four per cent of the children (n=80 out of 85) in the same group responded that science and technology are necessary for the development of the nation and welfare (see Appendix A.2 and A.3 for the details). They further indicated that the environmental problems are inevitable byproducts of the nation's economic development. In their ideas of development, economic growth and technological progress are dominant traits. While they acknowledge that the quality of the natural environment is deteriorating for the sake of economic programs.

On what basis have children constructed these paradoxical understandings between economic development and environmental destruction? What do their understandings have to do with the dualistic understanding of human being and nature? Their paradoxical ideas of the social development and the environmental destructions do not sound new or foreign to my understandings, because I also share my own conflict in this regard. In the social values systems of modern culture, I understand the importance of economic development and I appreciate certain outcomes of science and technology. I also try to question about my responsibility for making decisions toward creating a sustainable future.

William Rees (2002) points out that human cultures have developed a modern myth whereby human welfare can be equated with ever-increasing material wellbeing. Rees goes on to argue that this common ideology transforms decent, well-rounded citizens into "single-minded consuming machines." To cater to the demands of the myth, people always strive to find ways to gain more goods/services, thus science and technology have become the cornerstones for economic growth. "Many of us harbor the same double standard: we enjoy the benefits of technology while remaining largely ignorant of its inner workings. We have a society where…we have the outward acceptance of modernity without the inner conviction" (Mayor, 1999, p. 151). This is especially true in modern Korean society. As a newly industrialized country the idea of development or progress is closely linked with economic, technological, and westernized civilization (Kim, 2001). Material goods and technologies became solid indications of social development. On this ideological basis, it is easy to slip into the binary understandings between the development/progress of human welfare and the exploitation of nature (Berry, 1999; Keller, 1993; Rees, 2002; Wackernagel & Rees, 1996; Wilson, 2002).

> Our technological ambition must begin to scale itself down, allowing itself to be oriented by the distinct needs of specific bioregions. Sooner or later, that is, technological civilization must accept the invitation of gravity and settle back into the land, its political and economic structures diversifying into the varied contours and rhythms of a more-than-human earth. (Abram, 1996, p. 272)

With these contradictory ideas of modern civilization, science/technology, and the environment, children learn, adapt, grow, and become citizens of the society. Children are participants in the construction of this society. I am also one of those who lives through those contradictory ideas. To discuss these modern understandings of STSE, I question where and how as science educator I might start a conversation openly and sincerely with children. In so doing, I reflect on Heidegger's notion of *poesis* of technology and the saving power. I wonder how I might bring forth such reflections in our classroom conversations. Where there is the danger (negative consequences) of technological implications, there should be a way to overcome the situation through human action. The question was where and how we together find the saving power concerning the issues of STSE and modern values.

While pondering the inclusion of ideas, I realized that children's sensibility and awareness of responsible and sensible decision making could become a starting point of our discussions.

> It [scientific development] is positive but when we are getting benefits, nature is destroyed. It is good to progress our lives but it doesn't necessarily mean that our society is getting better. Because of the material oriented mind, our society is getting doomed. So my conclusion would be "it [the future] is getting more convenient but it doesn't mean that it will get more healthy and sound. (Boy, age 11)

> It is true that gas or sewage ...cause environmental problems. That's true, but now factories are trying to reduce pollutants. ...We really should take a look at how people live in their everyday lives to find the reasons of the environmental problems. ... I think we have to change our attitudes first. (Boy, age 12)

> We need to be frugal. Use less water and energy. That's the best way to solve the problem. (Boy, age 12)

The need for "saving power" was definitely growing in children's minds. Their awareness was contemplatively responding to the conflicting issues of modern science and technology. It is now the question how I am going to respond to their awareness and sensibility of STSE conflicts to understand the vision of scientific literacy. To reconcile the conflicting ideas, I need to learn how critically and responsibly respond to children's awareness and readiness of STSE issues in my teaching.

Entering the Phase II: A practice of STSE teaching

In this chapter, I have interwoven children's stories of STSE to understand the vision of scientific literacy in the contemporary era. As we hear the children's words, the discussion of scientific literacy needs to recognize the reciprocal relationships of children's understandings and social changes of science and technology in local and global contexts. Paul Hurd (1998) explains that scientific literacy must recognize the range of changing forces such as the emergence of an information age and birth of a global economy in order to have a valid interpretation of scientific and technological knowledge.

And I again think about the meaning of a major aim of the Korean National Science Curriculum: "to prepare students to become capable world citizens for globalization and information era in the 21st century." Science educators need to interpret what scientific literacy we as citizens would need in terms of the local as well as global contexts of science and technology. So I must keep the children's words in mind as we continue reflecting on the question of scientific literacy and science education. Children's context-sensitive, value-oriented, and emotionally lived though stories are ready to be explored and engaged in our visions of scientific literacy and making a future. The question is how the current science curriculum in Korea and elsewhere would embrace children's stories of science and technology and respond to the meanings of scientific literacy in a sensible and timely fashion. It is also how I mindfully and creatively teach science within the given curriculum to incorporate the implicit but vital role of contemporary scientific literacy.

With such questions in mind, I attempted to organize my teaching practice for the next phase of research following a three week break due to the school summer holidays. This three week period was a significant time for me to re-consider my plan for teaching the unit on the environment with a focus on STSE relationship in grade 6 classes in the following research phase. The next chapter will share the challenges of STSE teaching through my practice.

# CHAPTER 9

## REFLECTIONS ON THE PRACTICE OF STSE TEACHING: POSSIBILITIES AND CHALLENGES OF SCIENTIFIC LITERACY IN TODAY'S CLASSROOMS

### Introduction

In the light of the increasing concerns in relation to the environment – including global climate change, pollution, habitat degradation, and species extinction – my research interests in the area of environmental issues, as one among the various dimensions of Science-Technology-Society-the Environment relationships, have been growing. As I strove to incorporate children's understandings of STSE relationship in my teaching practice, I chose to teach a unit on ecosystems and the environment in Phase II of this study.

Through teaching this unit to grade 6 classes in Korea, I attempted to investigate the possibilities inherent in a view of scientific knowledge as connected to children's everyday life experiences for helping them to reconcile the conflicting ideas about science, technology, society, and the environment that I investigated in Phase I. Since the topics in the unit are primarily on ecosystems and the environment, this chapter initially explores the issues of teaching the environment in science classrooms and expands its discussion into the issues of scientific literacy and STSE teaching more broadly later.

The unit from the Korean national science curriculum for Grade 6 that I chose to teach was entitled 'Healthy Environment'. This unit includes subunit on ecosystems and environmental issues, listed as follows:

1. Identification of necessary living/non-living elements for living organisms
2. Explanation of different proportions among components in food pyramid (Producer > 1st order consumer > 2nd order consumer)
3. Explanation of the food web and ecosystem balance
4. Demonstration of understanding the natural and human causes of imbalance in and between ecosystems
5. The relationships between ecosystems and pollution and the need for environmental conservation

With those topics as the content of the explicit vision of scientific literacy mandated by the curriculum, I also attempted to examine possibilities for cultivating an implicit conception of scientific literacy, that is, a notion of scientific literacy that includes lifeworld connections and a view of scientific literacy as participatory and embodied knowledge. These ideas value the integrity of knowledge and action, the interrelatedness of being and living, and responsible participation. In order to examine these ideas, children's stories, classroom conversations, and reflective writings were extensively collected and interpreted.

As the research developed, I encountered various pedagogical challenges in teaching ecosystems and the environment to cultivate the connections between science learning and lifeworld. In this chapter, I share those challenges, interweaving with the stories of children's experiences, classroom learning, and social dimensions. The challenges will be discussed in three themes; as a) separations in children's understandings of the environment, b) disconnections between children's awareness and action, and c) the difficulties of engaging lifeworld values in STSE teaching. Each part shares children's stories, classroom episodes, and my reflection to discuss the possibilities and difficulties of cultivating participatory scientific literacy and STSE teaching.

The challenge of separation in children's understandings of the environment

As I understand the notion of 'scientific literacy as life knowledge', my teaching attempted to understand the ways in which children learn science within the context of their life world experiences. In children's understandings of the environment however, I found the gap among children's scientific knowledge of the environment (the concepts of ecosystems), their everyday experiences of the environment (city), and their desirable imaginings of the environment (nature) difficult to overcome in order to bring forth the connection between science learning and their everyday lifeworld.

*Nature vs. city environments*

When I asked children to share their experiences with the environment, one student shyly raised her hand and said, *"I don't have any story to share. I hardly go to the mountains or woods so I can't think of stories about the environment. I don't have any relatives to visit in the countryside either."* Later, I realized that most of the children identified 'the environment' as nature in their stories and writings. In children's understandings, the demarcation between the natural and human environments was noticeable. Within this dichotomy, the environment (nature) was seen as too abstract, elusive, and distant to allow students to understand it and experience its connections to their everyday lives.

This naïve understanding of the concept of 'environment' has been a common story in Korean science classrooms. In my science learning as a student, 'the environment' meant the biological concept of nature and ecosystems. Typically, teachers situated human beings on the top of their hierarchical classifications, and portrayed 'human' as the supreme creature, the controller over other species. The study of ecosystems and the environment consisted of learning about 'their' lives, 'their' habitat, and 'their' interactions. There was little recognition of ecological relations to the earth as a shared *home* (the word, 'ecology' is derived from *oikos* in Greek, meaning 'home'). This tendency has not been much changed, apart from presumably being exacerbated more than ever in the modern technological world.

During classroom conversations, a rather distant relationship with ecosystems and the environment was expressed by students. For example, Eunjoo, the female leader[14] of the class, a bright, collaborative, and thoughtful student volunteered the following in a class discussion:

> Honestly, when we learn the importance of ecosystems, it doesn't really call my attention. I don't see any environment [nature] surrounding me until I get to rural areas. I do not think about it much and even when I think about it, it doesn't feel close to me at all. It feels too far sometimes. I just learn what I need to study in the classroom but don't really think about it afterwards. (Girl, age 12)

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[14] Each class has two leaders, male and female. The leaders are elected by all the students in class in the beginning of semesters. Their roles are to help teachers and other students with class activities, to participate in students' school council meetings, and so on.

Eunjoo expressed her distant feelings about nature from her previous learning experiences. Through her verbal articulation, the abstraction and separation of the environment from the students' perspective became so real to me. It seemed difficult and even almost impossible to overcome this separation in a city like Seoul where the trajectory of children's lives occurs within the grey jungle of buildings, roads, and traffic.

> I am living in an apartment. All food is coming from the grocery store and all stuff that I need is from the shopping malls. I study at school and cramming schools…I play computer games at home or sometimes I go to PC game rooms too. I do my homework, watch TV, and read books…During the weekend, my friends and I visit each other or play soccer in the playground… I sometimes go to the mountains. That is the only time I experience the environment. (Boy, age 12)

More than two thirds of the participants were born in Seoul and have never lived outside of the city. They do not see the connection between their everyday lives and the environment – by which they mean the natural world. Children do not see their lives as part of living ecosystems. Their perception of ecosystems or the environment is as places to visit, not as something able to be reached every day, something within which they are embedded. They understand their lives as being associated closely with their technological surroundings rather than with natural environments. David Orr

(1992) explains that we face difficulties in teaching 'the environment' when all of us "move down the continuum toward the totalized urban environment where nature exists in tiny, isolated fragments by permission only" (p. 89).

With this situation as one of the 'givens' of children's everyday environment, teachers need to teach ecosystems and the environment as mandated knowledge in the curriculum, while making connections with a much broader and more inclusive notion of 'the environment' that includes the built and technological environments as well as the natural world. I tried to understand how to bring forth the connections between scientific knowledge and students' everyday life situations in this limited situation. I strived to cope with students' existing notions of the environment, through incorporating creative and innovative ideas and interdisciplinary approaches. I looked at the picture of food chain in the textbook. All of sudden, the rice field, grasshoppers, frogs, snakes, and eagles looked too remote and unrealistic to act as a lifeworld context within which to discuss my concerns.

*The gaps in children's understandings of the environment*

When the issue of the perceived separation between the 'environment' and the children's everyday places arose at the beginning of the study, I further examined the ways in which children related their conceptual knowledge with the issues of the environment. I attempted to understand the gaps in the children's understandings through their stories, verbal and written responses, and classroom conversations.

The children's understandings are summarized in a diagram, Figure 9-1. This figure shows different dimensions of children's understandings about ecosystems and the environment. Lines (a), (b), and (c) and the arrows across them explain the degrees of relationship and interaction among different facets of children's ideas. For example, when it comes to environmental problems, children's ideas tend to align with moral standpoints such as "that is a right thing to do" or "harming animals is not ethical." Or they are related to aesthetic perspectives such as "it destroys the beauty of nature" or "we can't find a place to relax."

The thickness of lines (a) and (c) indicates the isolation of scientific knowledge in children's understandings of the environment and environmental issues. Not much scientific knowledge was included by children in their responses related to issues such as interdependence among species or the balance of ecosystems and reasoning or decision making over environmental issues. Scientific knowledge such as water/air circulation or energy concentration in ecosystems and human impacts on them hardly appeared in children's discussion. Rather, their understandings were based in ethics and aesthetics, the notion of the environment as a 'good place'.

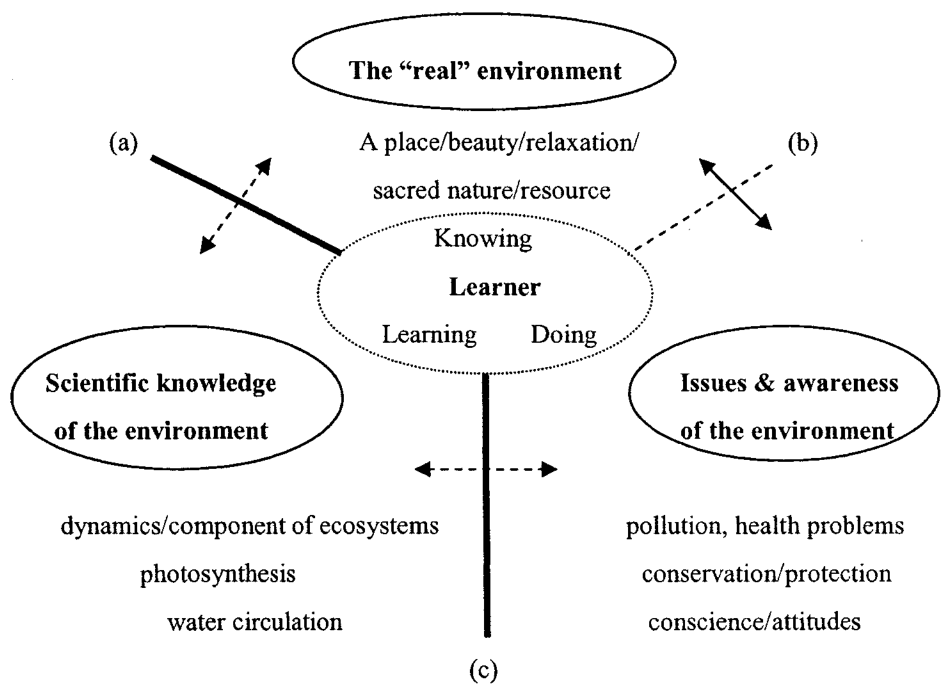


Figure 9-1. Children's understandings of the environment

Some researchers have indicated that there is no strong evidence that scientific knowledge is the main source of decision-making in science-related circumstances in our daily lives (Bell & Lederman, 2003). Bell and Lederman's research explains that understandings of scientific knowledge played an insignificant role in the majority of the (adult) respondents' everyday decision making. On the contrary, sociopolitical issues, ethical considerations, and personal values, as well as emotive dimensions such as feelings and intuitions, appeared to dominate the participants' decision making on complex issues such as environmental issues (Berry, 1999; Bateson, 1972; Damasio, 2000; Dillon, 2002; Johnson, 2004; Kollmuss & Agyeman, 2002; Lakoff & Johnson, 1999). In this regard, it is critical in STSE education to better incorporate students' lived experiences, emotive learning, and value systems with scientific and technological knowledge and their implications for modern society and culture in STSE teaching.

However, some questions arise in my mind. If scientific knowledge rarely influences our decision making, is it effective for STSE teaching to emphasize only moral reasoning in order to bring forth responsible citizenship? Does scientific knowledge naturally have no relation with our decision-making process? Or does this occur because we teach scientific knowledge separately from the complex contexts of decision making? For example, we teach the concepts of food pyramids and energy concentration as scientific knowledge in one class, and we address the environmental issues as moral and social concepts in another. Possibly due to this disconnected way of teaching, there might not be much connection between our decision making and the scientific knowledge we have learned. I do not claim that decision making based on moral and internal values or societal perspectives is inefficient or insufficient. My question is rather how science education can better help students to understand STSE issues and decision-making through learning rich scientific knowledge, so that they can learn the implications of scientific knowledge in practice.

To my understanding, this would be an important task for the development of STSE education. Without such an effort, scientific knowledge will remain in the separate domain of knowledge developed – and maybe only ever used – in classrooms or science labs. However, as my experience of teaching and of the children's stories developed, these questions became more challenging and perplexing, without suggesting clear and firm answers to me. I realize that much further reflection and research is required in this area and that this requires of me another long journey.

The challenge of the disconnection of children's awareness and action

Given that STSE education aims for students' critical thinking, decision making, and taking action based on their awareness and sensitivity, I attempted to examine how children's experiences and awareness affected their attitudes and behavior in relation to environmental issues. Through STSE teaching, we expect to cultivate awareness of STSE issues so that this awareness can support students' decision making and action taking. However, do children's awareness and consciousness always lead with actions to follow? How does one become bodily and mindfully engaged in responsible understanding? As scientific literacy and STSE issues are value laden and (ideally) involve action, thriving for connection between awareness and action taking becomes an important aspect of STSE teaching. This also challenges us to cultivate the ethics of scientific literacy through STSE teaching.

*Children's passive awareness*

The children in the study experienced environmental destruction through their lived experience. They expressed regret through a number of striking visual images:

> I was on the way home. I started coughing hard. A car honked really loud on the road and made my ears dizzy and numb. I got so scared of breathing the air from the car. I had never realized about air pollution that seriously before. (Boy, age 11)

> I saw a dead frog floating on the water. So were garbage, pop cans, plastic bags, and so many other things. I felt appalled and disgusted. Why did people do such things? (Girl, age 12)

> I was visiting my grandma's place on countryside. I saw a huge construction site to make a tunnel in the mountains near the highway. I realized when we have convenience, nature is suffering. (Boy, age 12)

> I smelled a terrible sewage smell. 'Where is this smell coming from?' … Garbage was decaying on the corner of the street. Wherever you go, you see garbage, even in mountains and small rural towns. That's too bad. (Girl, age 12)
>
> (My experience of the environment)

With these lived experiences and awareness as a context, we would assume that children would be encouraged to take proactive attitudes and to take action toward environmental issues. Despite their awareness, however, various reasons were advanced by the children for not trying to change or develop good behaviors for/in the environment.

When children were asked why they did not take action, despite their awareness of environmental problems, they explained their reasons as follows:

> Now I am nothing but a child so there is little I can do…when I grow up, I can do better things for environmental protection. (Girl, age 11)

> …But there are some things that I can't do. Polluted gas from cars or waste from factories should be taken care of by those who use those. (Boy, age 11)

> We think that my onetime misbehavior wouldn't harm the environment that much. Or we think it would be ok that it is only me doing this. We hope that somebody else will do the right things for the environment, not me. (Girl, age 12)

> If we really want to protect the environment, we have to live like people in Joseon Dynasty (in the 16th century of Korea). That's

> impossible. We shouldn't use shampoo, cars,... almost nothing... How can we live like that today? (Boy, age 11)

Children have developed an attitude of 'spectatorship' toward the environmental problems, regardless of their first-hand experiences and awareness. Some students feel they are too little to take any effective action toward certain environmental issues. Some parts of the world only belong to adults, not to students. Some parts are too far away, too abstract and immense for them to take on at an individual level. Problems are expected to be dealt with some other time and by some other people.

Along with these individual conflicts, children's passive awareness is also developed through their interactions with others – peers and the community. Children explained this factor as follows:

> I cleaned the side street, picking up all the garbage one day. An hour later, I saw there was again much garbage around and I felt so mad at other people who littered. It made me wonder if I did something useless. (Boy, age 12).

> My friends would tease me if I do good things such as picking up garbage on the street or any thing like that. They sometimes say, "Ya, ya, ya, you are good" in a very sarcastic way. When I am with them, I do the same as they do. (Girl, age 12)

Fruitless efforts and lack of community collaboration make them feel disappointed and uninterested in taking on another endeavor. Peer pressure is another factor that influences children's action taking.

The following table is the summary of the children's various reasons.

Table 9-1: Barriers to change in children's behavior (Total n=45)

| ***Why is it hard to take action or change behaviors for/in the environment?*** |
|---|
| Selfishness (n=10, 22.2%) |
| Laziness (n=7, 15.6%) |
| Bad bodily habits (n= 7, 15.6%) |
| Using everyday products is inevitable for us. (n=7, 15.6%) |
| Nature (the environment) is too far. (n=4, 8.9%) |
| Not enough social/community based program (n=4, 8.9%) |
| I am too little to change the problems. (n=3, 6.7%) |
| Frustration and distrust from unfruitful efforts and lack of community collaboration (n=2, 4.4%) |
| I don't know how. (n=1, 2.2%) |

Seen in the children's examples, there are many variables that cause disintegration among awareness, attitude, and behavior – for instance, internal conflicts, social and cultural norms, and traditions. Kollmuss and Agyeman (2002) explain the complex relationships among demographic (gender and years of education), external (institutional, economic, social and cultural), and internal (motivation, environmental knowledge, awareness, values, attitudes, emotion, locus of control, responsibilities, and priorities) factors as significant players in pro-environmental behavior. In my study, considering that the participants are sixth graders, some factors such as economic or educational background did not play a large role in the children's attitude or behavior, however, internal factors such as emotive experiences, tender age, bodily habits, peer interactions, and discouragement by the lack of community support were conspicuous. Confronted with those various factors, their awareness or consciousness of environmental issues did not necessarily bring forth actions or behavioral changes on the part of children. In the disconnection between awareness and action taking, we encounter the challenge of participatory roles of STSE knowledge because passive awareness cannot bring forth responsible or effective implication of knowing in life contexts. This also challenges us with ethical concerns about the integrity of knowledge in STSE education.

Some raise the criticism that we have relied on simplistic cause-effect model of knowledge and behavior in value-based education (Juarrero, 2002; Kollmuss & Agyeman, 2002; Mainteny, 2002). For example, addressing ethical dilemmas of science and technology, STSE education has aimed to help students make responsible decisions and take ethical action. Traditionally its approaches have tended to view critical thinking, decision-making, and taking action as a linear process. That is, when knowledge is learned, attitudes and then behavioral changes will follow. However, such reductive models cannot encourage and cultivate children's ethical action and behaviors on STSE issues as illustrated in the children's stories. To encourage participatory and responsible roles of scientific literacy, STSE education needs to reconsider ways of addressing STSE issues and embodying the issues in our action.

*Encouraging children with the integrity of knowing*

When our knowing cannot be completed by our action, we are lacking integrity, the ethics of knowing. In this regard, the children's passive awareness opens another pedagogical question in STSE education. In order not to become another dimension of conceptual knowledge, STSE education needs to take into consideration the disintegration of knowledge and action, emphasizing the participatory role of knowledge.

With the notion of integrity of knowing - Confucius "cheng" and Varela's "immediate coping," children's passive awareness, the difficulties of action taking, and the integrity of knowledge and action can be examined and contemplated in STSE classrooms. When we understand the ethics of knowledge is not only 'knowing about' but 'knowing and acting with/in', addressing ethical dilemmas in STSE classrooms challenges another dimension of ethics, that is, ethical participation and action which emphasizes the responsible roles of scientific literacy.

Such an attempt to bring in the integrity of knowing and ethical dimensions involves children's subjective, emotive engagement. In the study, the children reflected on their disintegrated actions. Whatever their reasons, children felt uneasiness when their actions were not integrated with their awareness. There were feelings of shame, regret, and dissatisfaction in their reflections:

> I felt a bit ashamed when I did that… (Girl, age 12).
>
> I throw garbage away quickly again… Then I kept thinking to pick the garbage up. "Pick it up, pick it up" in my head but my feet kept walking, moving away, far away from the garbage… then my hand already littered it at the moment people didn't watch me. I sometimes think I wish I could throw this shameful feeling away with the garbage too… (Boy, age 11)

On the other hand, there were also children's fulfillment, confidence, self-esteem, motivation, and encouragement when they tried to complete their knowing and learning through their action.

I thought about soil pollution and water shortage. I learned from school, books and TV documentary films on garbage problem, soil pollution, water shortage and lack of resources, and so there would be many diseases around.
There are so many things that I like to do in the future.... I want to be a singer but what if the earth got too polluted and no one could be alive...I feel frustrated.
I decided to finish food even though I don't like to, but it's not easy. But I didn't give up and have been trying hard. Now it seems that I became a big eater. "When I try things consistently, I can change even my bad habits," suddenly I thought. Now I am trying to use less water. I don't run water while brushing my teeth and so on. And I am using environmental friendly soap and shampoo. If all of us could live like this for one year, our place would be nicer and cleaner. And that would change my future and let my dream come true. I am eager to share my ideas with people so that we could live more frugally. (Boy, age 12)

My younger sister had a bad habit. She always leaves a little bit of milk in her glass. My mom and dad always told her to finish it but she didn't listen. She says, "I finished, I finished." But there was always a bit left. So I suggested doing one experiment that I did at school. I brought a big transparent bowl and water and put the milk to the bowl. And I added water. It was still milky white and I added more water and more water to make the mixed liquid look like water. A lot of water was needed to make the water clear. My sister was surprised and she told me that she would be more careful.
"We think that this little thing won't cause any trouble in the environment but it is not a good attitude for a person who cares about the environment, you know?" I told my sister. I felt proud of myself. (Girl, age 12)

When I heard these stories, I realized that discussions about the ethics of STSE knowledge could be possible with children. Children's positive and empowering experiences of their integrated action have much potential to overcome the disconnection and passive awareness of STSE knowledge. Acknowledging and encouraging children's experiences of fulfillment with integrity, we can cultivate possibilities for the ethics of scientific literacy in children's knowledge.

Heesoon Bai (2001) argues that one's ethical embodied mind is required in order to empower one's "knowing-in-action." To embody integrity and ethics in our everyday action, we strive to train ourselves in good habits of mind through reflecting on what we know and what we do, and letting our desire go in order to embody the mindfulness of action (Bubryun, 1994; Hanh, 1999; Lakoff & Johnson, 1999). As seen in the story of the boy who embodied his concerns and awareness about the environment in his action – finishing his food and shutting the water while brushing his teeth, one's mindful reflection and practice can embody one's knowing in action and become part of one's being and living. While he attempted to practice his knowing, he also experienced fulfillment and confidence in his mind. This positive experience of mind encourages one's integrity in action (Batchelor, 1992). Such development and discipline can be a way of transforming passive awareness into solid and participatory grounds for knowledge. This process requires our consistent and collective efforts, which challenge us the most to cultivate an understanding of scientific literacy as embodied knowledge.

The challenges of engaging lifeworld values in STSE teaching

In developing an understanding of the role of scientific literacy in lifeworld, I found engagement with the issues and values of modern society and culture was another challenge of STSE teaching. While teaching the unit on ecosystems, I attempted to include discussions of everyday life values in classroom conversations. In such a way, I intended to develop children's learning through these connections to enable them to reconsider the environment with an understanding of the concepts of ecosystems and lifeworld values.

*The lifeworld values in ecosystems and the environment*

Many authors have argued that sociocultural traditions, values, and ideologies are closely engaged in decision making in socioscientific and technological contexts (Carr, 2004; Morito, 2002; Orr, 1992; Rees & Westra, 2003; Sadler & Zeidler, 2004; Zeidler et al., 2005; Wilson, 2002). In STSE discussions, particularly in relation to environmental issues, modernist values and ideologies are deeply embedded in our understandings. During the classroom conversations, I invited children to share their ideas and values around ecosystems and modern life. These ideas were evoked and challenged by those of the other students. As we tried to understand ecosystems and the environment in relation to everyday life, children often brought up their value judgments and feelings, and their life experiences as illustrated in the following classroom example:

> **September 9th, 2003**
> The class was working on necessary elements of the living and non-living in ecosystems. I asked the children to come up with necessary elements for living beings to stay alive. They said natural elements such as water, air, sunshine, and soil. Since we tried to make connections between our being and the environment, the questions also moved on to 'my everyday life'. When I asked, "what are the essential things for us to live?" children responded with several answers. And, suddenly Seo-Ho shouted, "Money! Money can bring us everything we need." As he answered, a few students reacted with strong agreement. Some repeated the answer with him, "Yes, money, money." They didn't stop until I wrote the word on the board. I realized that we needed to talk about the relationship between money and our lives since it seemed to be an important and intriguing issue for us at the moment.
>
> Teacher (T): Why do you think money is the most necessary thing that we need?
> Seo-Ho (S-H): We can buy everything with money. If we don't have money, we would die.
> T: What do we buy with money?
> Students: Food, books, we go traveling….
> S3: We need go to hospital too when we are ill.

T: Among those things, what do you think is the most fundamental thing for our everyday living?

Students: ...eating food... Being healthy maybe?...

T: Then where is the food coming from?

Students: Land, ocean, farm...oh, factory too. canned food! (laughter)

T: So when we trace it, it goes to where?

Students: Nature, the environment

S-H: But it is true that money is very important. If you don't have money, you can't survive. Yesterday I heard one person committed suicide because he couldn't pay his credit card debts. It was a lot of money.

T: Is there any one who has any opinion on this issue? Do you want to share it with us?

S1: I think money is important too but it is his fault not being responsible.

S2: Also I think there are some things that we can't buy with money.

T: For example?

S2: Ummmm...

S5: Health

S3: But we can also buy health products or go to hospital to cure our illness.

S4: Yes, but we can't cure everything.

S5: Then I should say life. We can't buy life.

T: What else?

S6: Happiness?

T: What else? What about... umm...can money revive everything that disappeared?

(a pause)

T: What about like extinct animals or polluted ocean?

Students: Right, we can't bring them back.

S5: Maybe some of it.... It will take a lot of time though. Han-River was really polluted a long time ago but now it is clean. I saw people fishing.

T: So we know there are things that we can do with money and we can't. So what would be important for us in terms of money and our environment? We will develop more ideas on this issue later.

> We got back to the topic, the elements of ecosystems and the relationships with living/non-living beings, and later the class ended.

In the attempt to connect the children's everyday lives with their knowledge about ecosystems, the ideas of capitalistic values and human lives often appeared in our discussions. With the understandings of the dynamics of capital and its value in modern lifestyles, children sometimes encountered challenges in their decision making on environmental issues. For example, they desired for the value of capital and technological development as necessity to the 'goodness' of life more than a sustainable environment. This indicates that our understandings of a sustainable human environment has depended heavily on technological solutions and market oriented ideologies and strategies, which are becoming ruling structures of our mind systems (Braham, 1988; Carr, 2004; Fisher, 2002; Orr, 1992; Ziman, 1980). The following example also reflects on this notion.

> **September 24th, 2003**
> Teacher (T): What has your group come up with as possible solutions to the environmental problems?
> S1: We have some thing similar to other groups. But we have different ideas too. Throw garbage to other countries. [laughter]
> T: What do you mean?
> S1: Sending garbage to other counties by ship, plane, or…
> …

S3: But teacher, I heard that there are some countries which take garbage from other country. I think we can do that when we cannot solve the problem in our country.

. . . .

S5: Yes, I heard that people could export garbage to some countries too.

Children mentioned garbage export as a solution to garbage problem since they learned the idea from TV and the internet (see Appendix E for more children's discussion). Some children did not view that the earth was one ecosystem whose sustainability was depending on our collective responsibilities. In the international society connected through the global affair and trade, other countries can be another solutions to local problems and limitation. The realization that the earth is one shared world is in some ways quite a recent one whereas self-centeredness has been a feature of local and global societies throughout history.

Seen in children's discussions, the values and events of modern society are deeply embedded in children's understanding and decision making on environmental issues. When children experienced difficulties in reconciling their everyday values, social features, technological convenience, and environmental issues, I also questioned about in what way my teaching could help them with their understanding of environmental issues and values in terms of building a sustainable society. In this regard, my STSE teaching faced much challenge in denoting limitations on human ambition and to define the roles of citizens within social and cultural values.

*Reconceptualization of modern ecosystems*

With the discussion above, I reflected on how STSE teaching could co-construct values related to nature, our everyday living, and social conditions. I tried to cope with the separation between children's science learning and their everyday understanding of the environment. I encouraged the children to share their everyday experiences in terms of 'our living' so that we could link our everyday connections to the here and now. During the class, children were asked to come up with necessary elements of their everyday lives and understand where the elements (objects) come from and how they relate to each other within the environment. Figure 9-2 below is an example of children's group work on these questions of 'I' in relation to city ecosystems. Children wrote down a list of the things they use in their everyday lives and tracked down through the previous processes that the objects have been through until they cannot go any further. They were asked to put a mark, *, to indicate features of the natural environment on their diagram later.

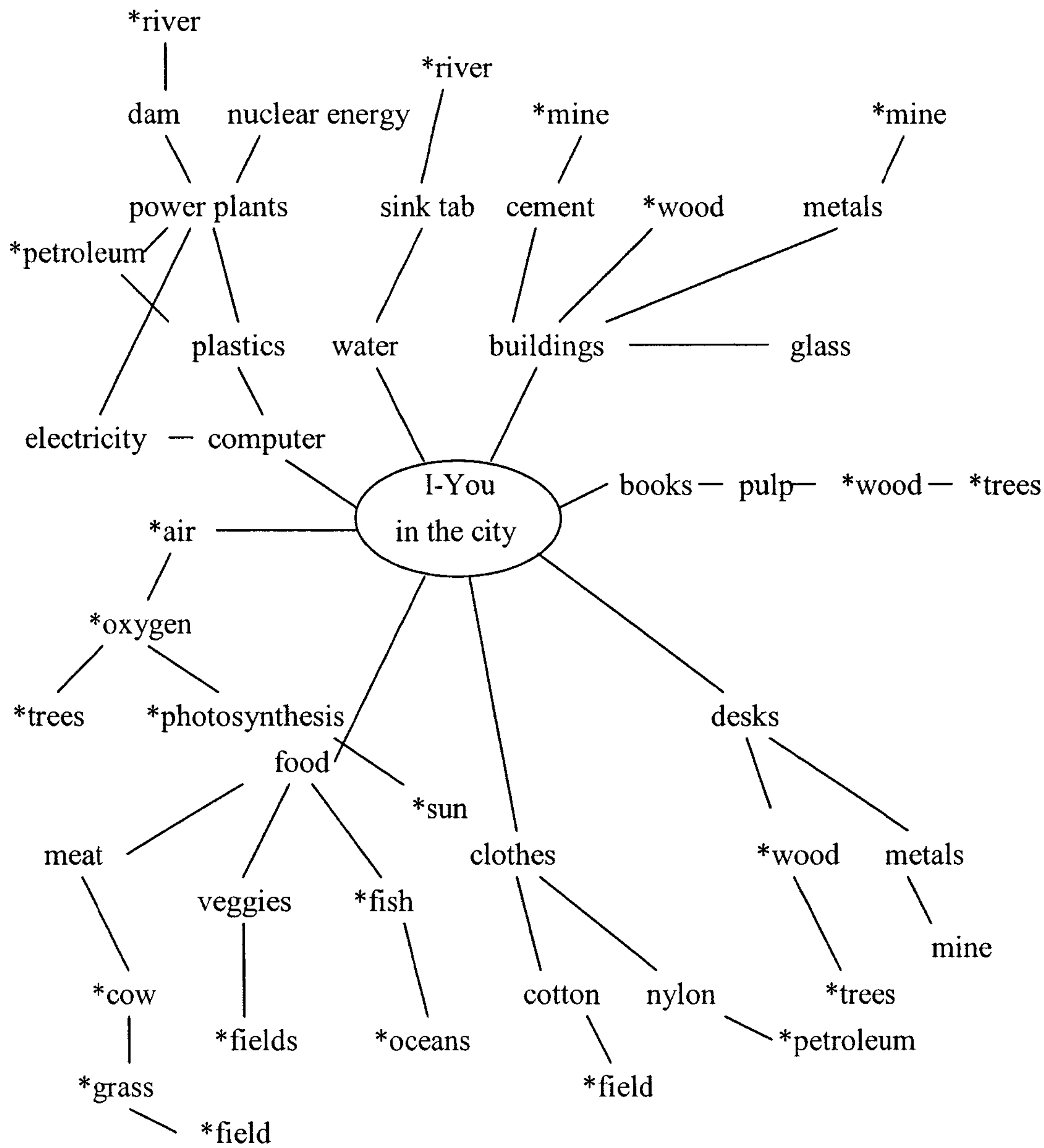



Figure 9-2. I-you in a city ecosystem

This is a sample of children's group work (n=5). Students were asked to put * to characterize a natural element in the environment.

After drawing the basic diagram, the children were also asked to put lines where things were connected. Later, the diagram was almost completely covered with lines. Children responded that everything they use originated from nature and that everything is connected to natural ecosystems. A small thing like a pencil had a huge set of connections, they said. It was one of the activities concerned with our nestedness in the environment.

In a traditional sense the concept of ecosystems is a study of the natural environment, commonly taken as a hierarchical system of biota and biotic interactions of matter and energy. There is not much sense of our presence in the flow of ecosystems.

> In the extreme this dichotomy emerges as a distinction between community – the system of populations – and ecosystem of matter-energy transformations through biota and environment. The separation of community and ecosystem ecology in textbooks and classrooms is evidence of the acceptance of this dichotomy (King, 1993, p. 22).

Incorporating an understanding of ecosystems as an integral part of the world system, a process-functional approach (King, 1993) requires us to understand the transfer and process of matter and energy as having integral relationships with humans and the dynamics of living organisms. Within the dynamic flows of modern society, it is also imperative to acknowledge the participation of non-human actors such as artifacts and technologies in the environment (Kauffman; 1995; Latour, 1999).

Nonhuman entities are mediators in the framework and network of events and interactions with the environment (Braham, 1988; Capra, 1996; Latour, 1999; Portugali, 2003). That is, we understand that abiotic and technological objects mediate and structure our being and living within the whole network of relationships rather than seeing them reductively as mechanical "things" with separated boundaries. Fritjof Capra (1996) emphasizes that relationships are primary and the discernable boundaries of objects are secondary. In systems thinking, "nature is seen as an interconnected web of relationships," explains Capra (p. 38). Anthony King (1993) also points out that:

> System integrity implies the integrity of both system structure and function, a maintenance of system components, interactions among them and the resultant behavior or dynamic of the system - e.g., succession or the processing of energy ... Indicators of ecosystem integrity associated with human value judgments, like economics or aesthetics, should not be excluded by a prejudice for natural, ecological or scientific perspectives. (pp. 25 - 27)

Within such a concept of system integrity, our knowledge of ecosystems and the environment emerges from an understanding of our intersubjective and interobjective being and our place in the web of relationships, rather than from the logic of a theory itself. Within these interrelationships, I am also continuing to learn the possibilities for scientific knowledge to be developed to include a rich understanding of its lifeworld connections and of human values and ethics.

Reflection

Through STSE teaching practice, I attempted to learn possible ways of cultivating scientific literacy as life-connected, participatory knowledge. As I understood that I needed to take into account not only explicit (concepts and skills) but also implicit (attitudes and behaviors) scientific literacy, I was challenged to incorporate the two dimensions through my teaching. Reflecting the challenges of separateness, disconnection, and conflicting values in children's understandings, I tried to find possible ways of understanding scientific literacy with life connections. The challenges continue to challenge my understanding of STSE education. During the process, I learned there need interdisciplinary and consistent efforts in STSE education in order to cultivate connected, embodied scientific literacy. And my research is one of the attempts which look for the possibilities of life-connected scientific literacy and STSE teaching.

Along with the challenges of children's scientific literacy, I as science teacher experienced the challenges of pedagogical dilemmas in STSE education. In Chapter 10 I will share the pedagogical conflicts around science teaching that I lived through in order to continue to contemplate on the internal challenges that today's science teachers encounter in themselves through everyday practice of STSE teaching.

# CHAPTER 10

## REFLECTIONS ON PRACTICING HERMENEUTIC RESEARCH

Introduction

Entering the research, I expected to find solutions and answers to my research questions about STSE education and scientific literacy. My mind was consistently seeking for solid conclusions that would finalize my research. Instead, the research offered more challenges and questions than answers in the end. I was confused and concerned about the research process which could not bring me closure in its field.

While seeking for solutions to the research questions, I was often challenged by my own being whose responsibilities are interlocked in science curriculum, children, and life relationship in modern society. Learning my relationships to pedagogy, children, and society, I realized the research was questioning about 'who I am' and 'how I act as teacher and researcher', not only what STSE teaching and learning was about. It was opening new questions, new beginnings, and new relationships among the research texts. In this process of research, there was no final conclusion or closed end but a process of learning my being in STSE education.

David Jardine (2000) explains the nature of hermeneutic inquiry as follows:

> [Hermeneutics] distinguishes itself from other forms of inquiry by its essentially educational nature. That is to say, hermeneutic inquiry has as its goal to educe understanding, to bring forth the presuppositions in which we already live. Its task, therefore, is not to methodically achieve a relationship to some matter and to secure understanding in such a method. Rather, its task is to recollect the contours and texture of the life we are already living, a life that is not secured by the methods we can wield to render such a life our object (pp. 115-116).

As hermeneutic inquiry entails a "restoring of life its original difficulty (Caputo, 1987, as quoted in Jardine, 2000, p. 117), my research was bringing to me the essential difficulty of life being revealed through an engagement of the challenges of being an STSE teacher. I had to understand the difficulties of being an STSE teacher in time and place of children, curriculum, and contemporary society "that are concealed in technical-scientific reconstructions, concealed in the attempt to render human life objectively presentable" (Jardine, 2000, p. 118). Based on these understandings, this chapter explores the hermeneutic process of my being and becoming an STSE teacher through the pedagogical dilemmas that I lived through with children, science curriculum, and social milieux.

Pedagogy of Aporia: The teacher's dilemmas

As I understood my being intermingled in the relationships of children, science curriculum, classroom condition, social expectation, and my commitment to STSE teaching, my teaching became more challenged and intricate. When some dimensions conflicted with each other, I encountered difficulties of decision making in my action. For example, with my responsibility for the curriculum and evaluation, my commitment to STSE teaching seemed to become weak and sometimes even forgotten. When children's learning was tightened up with the busyness of extra curricular, activities, exams, competition, and social expectations, I questioned in what way my science teaching could/should relate to their beings as a student, child, and citizen. When I thought about children as citizens of a sustainable society, I was committed to value-laden STSE approach. At the same time, I was well aware of science curriculum and examination which would directly affect children's relationships with their confidence, parents' expectation, and school lives. Understanding the importance of both contexts, I was struggling to position myself in science teaching. My personal, pedagogical, and social being strived to learn how to be and how to teach within such conflicts. I was encountering a moment of aporia.

Hans Smits (1997) explains that in philosophical terms, *aporia* in Greek means a state of being at a loss, of attempting something that is impossible. It is focused on dealing with a doubtful matter, or a perplexing, difficult situation. Aporia is our experience of situations that seem so complex and abyssal that one cannot easily understand and find a solution to their complexity. One, being puzzled and confused, tends to ignore or give up on understanding the truth of the complexity. However, Smits suggests that aporia is the very moment in which we could have fundamental and creative dialogues to understand the meaning of complexity. Being in the chasm of contradictory realms, we experience uncertainty, and yet, because of this unfixed-ness and indecision, our ideas can also be full of possibility, creative, and innovative to allow us to wade out of the chasm.

The aporia during the research challenged me with many unanswered questions and confusions, nevertheless, it surely led me to contemplate teachers' responsible decision making and action in the midst of educational dilemmas. I tried to understand the meanings of aporia with a critical and patient mind. I tried to take the moment of aporia as an opportunity to enhance my pedagogical growth but it was not an easy task to be a hermeneutic teacher in science classrooms where the reality of science teaching seemed too fast, too crowded, and too pressuring to me.

*Aporia I: The difficulties of praxis*

> The hallway was so busy. Children were running around. They were laughing and talking loud. Full of energy. The bell rang and children came in the classroom. *My lesson plan is ready. Much to do...* My mind became also busy. Children were sweating. *I like to start right away.* Children were sweating. The two fans hanging on the wall looked so small for forty four students on a muggy day with 32 degrees Celsius... and I looked at the lesson plan in front of me...
>
> (the researcher's journal entry)

School was indeed a busy place. I was pressured by the speed of the curriculum. Time seemed to be rushing me to teach fast in order to keep up with the pace. In the rapidly erupting reality of the classroom, I wanted to look for technical and top-down strategies to control overwhelming classroom situations. In spite of my understanding of the impossibility of immediate outcomes in value-laden, interdisciplinary STSE education, my desire for concrete 'evidence' or 'proof' of it effectiveness through children's work was greater than I expected. My valuing of the importance of children's interactive learning and mindful pedagogy clashed with disappointment. I felt new to and ignorant in the classroom environment.

With these challenges in the classroom situations, STSE teaching became even more challenging. How do I effectively and mindfully practice STSE curriculum? Where do I find time to incorporate the meaning of life connections and citizenship responsibility in the curriculum content? I realized how easily STSE teaching can be given up and forgotten in the busy curriculum. STSE teaching was hard to negotiate.

I had often heard about the gap between educational theories and the reality of practice. And yet I had not really understood the difficulties of praxis until I lived them during this teaching practice. My mind was pressured to understand the reality of classroom situations and the possibilities of STSE teaching and mindful pedagogy. I learned to negotiate different agendas of teaching. I learned to make decisions within pedagogical dilemmas which were beyond my control. And during that time, I became more compassionate toward student teachers who would encounter the challenges of praxis of STSE curriculum in their future. Facing with the unexpected challenges of praxis, they might become disinterested and even doubtful about STSE curriculum. As my own mind had slipped into disappointment and disempowerment, they would also experience their difficult times. I would need to have more sincere and thorough discussions with them, sharing my experiences and the struggles that I lived through. The aporia of praxis will still be there and surprise them as they enter classrooms but at least they will know they are not the only ones going through difficult times with STSE teaching.

*Aporia II: Teaching children and teaching science*

I was often blinded to the children's stories due to my own busyness with teaching. Within the prefabricated agendas of the science curriculum, I concerned myself with questions of what to teach and how to teach. I forget to question who I was as a teacher to the students within the very moment. I became disconnected from their time and place that easily.

In order to focus on the experience of the students, as part of my research I concentrated on one student's regular school day. Kyung is a gentle and quiet boy. He doesn't talk much in front of the class but he is insightful and responsible about his work. He collaborates well and works diligently on assignments. One day, I saw him working alone during lunch break. I sat down with him, and we worked together and talked about our daily routines. After the conversation with him, I began to wonder about today's children, education systems, social expectations, and my being as a teacher. The following poem on the left side is my reflection after our conversation. The news article on the right side helps to understand one aspect of the education system in Korea.

***A Dialogue with the boy, Kyung***

A boy's week
Kumon[15] every Monday and
Wednesday
Nunnopi every Tuesday and Thursday
Drawing lesson Tuesday
Algorithm Wednesday
Science world Thursday
In two mornings, English telephone
conversation
And still need more work.

There is only 24 hours a day.
School
Assignments
Cramming school
Another class
Do you still have time to play?
Do you still have time to dream?
I cannot be slow.
Being slow is not good.

Lost dreams,

**A news article**

**Oct. 13/2003, *The Joongang Daily***

More education competition

...Past administrations have come up with enthusiastic education policies but most of them have had lame endings. As a result, our nation's expenditure ratio on private education is 6.8% of gross domestic product, placing it first among the 23 OECD nations, but in efficiency we have the dishonor of being 23d...In order to solve the problem of private education, it is critical to start from where our nation's education went wrong. Why is public education unable to carry out its proper role? As we have repeatedly stated, at the core of the problem lies the destruction of competition in education. Standardizing areas where standardization is impossible only makes matters worse. Populist policies cannot be applied in education. If there

[15] Kumon and Nunnopi are daily studybook programs run by private education businesses.

Forgotten breaths,
But the remembered class schedules
The Math school is at 5:00 pm.

"Wanna play soccer?"
Leaving all the tempting voices behind
I go to the Math school.
Heavy walking
Heavy mind
Uh, the bus is waiting, so I must run!

is a problem in withdrawing the standardization policy at once, it is necessary to set up principles and go about solving the issue gradually. The way to introduce competitiveness has been repeatedly presented. If there are solutions, why stick to unreasonable ways?
(Available *at www.joins.com*)

Kyung is a hard-working student, trying to live up to his parents' expectations and to excel and succeed according to the criteria that our society puts forward. Kyung's story does not apply to all children, but it is not a rare case either. In a situation where the pressure of school work overwhelms children and where the private education sectors chaotically take place to meet with parents' expectations, school teachers struggle with the complexity of the relationships among children' lives, the mandated curriculum, community and social expectations, and their own pedagogical devotion and authenticity.

> With the competitiveness in society, education systems face much conflict. The virtues of nurturing and caring are disappearing. There is individualism not interdependence, competition not compassion, and solipsism not solidarity… I do not know where to start a conversation with children for a sustainable future in science teaching so that they feel connected and care for each other and the world. .....*But what*

> *does my science teaching have to do with that? What they need right now may be only good scores anyway.* This thought exhausts me...
> (the researcher's journal entry)

Where the demands and expectations of children's excellence in test scores or performance are very serious, the framework of ecological science education can be perceived as impractical in terms of educational productivity. Memorizing content knowledge of science becomes the main concern in order to assure that children excel in standardized tests. These imperatives place pressure not only on children's and parents' shoulders but also on teachers' practice. Where competitiveness has been overly emphasized in the society, education becomes narrowly institutionalized.

The more I was close to children and their lives, the more I was challenged by my actions and reactions to the curriculum and to current social situations. My sensitivity was seeking responsible and pedagogical participation in my relationships with children. I hoped that my teaching would encourage them to deepen the values of ecological knowledge. At the same time, I hoped that my teaching would help them perform well in their academic competition. I worried about whether the meditative mode of teaching could bring unsatisfactory results on the test that the students would sooner or later take. I consistently ensured that I did not miss any concepts from the mandated curriculum for their school exams.

This conflict perpetuated itself throughout the research. In conversations, body language, (re)presented curriculum, and unsaid classroom dynamics/tensions, I could see myself positioned between being a teacher of children and of science. I hoped to teach both for ecological scientific knowledge and for academic performance. Is it possible to successfully teach scientific knowledge for good test scores and to empower their responsible knowing in their life contexts at the same time? How can I teach science to meet children's needs and the goals of scientific literacy within the existing social milieu? How do I dwell in both contexts without feeling exhausted and disintegrated? These questions also indicate the difficulties of cultivating implicit scientific literacy (responsibilities of scientific knowing) while teaching explicit scientific literacy (scientific knowledge and skills). I should not discard either of the goals. I continue to struggle with these questions, and they will never stop challenging me.

*Aporia III: Good teacher and responsible citizen*

Being responsible for children, curriculum, and the society, I was expected to be a 'good' teacher - smart, diligent, caring, and docile. Taking into consideration my understanding of teaching in relation to social relationships, I questioned whether the nurturing, hardworking, and obedient teacher in the curriculum could be creative, critical, and responsible citizen. What does the good teacher need to do to be a good citizen? How does teaching for good scores contribute to making a better society? Being in a conflicting time in Korean society, as both teacher and citizen I questioned how my teaching could be integrated with my concern of being a citizen in this time and place.

With the influence of the complex set of social demands and expectations toward science education, science teachers could simply aim their teaching for the preparation of students and themselves for employment and citizenship through the development of marketable values (Brown & Jones, 2001; Kincheloe, 2004). Critical perspectives on science curriculum or students' life knowledge would not necessarily verify the goodness of science teaching as long as students perform well on tests. This dilemma was also mine. The tension between my awareness of STSE issues and the expectations from others – co-workers, parents, and the society *per se* –often positioned me in the midst of the puzzles of being the 'good teacher', the dedicated teacher but with a mind obedient to institutional power. As Deborah Britzman (2003) explains we as teachers live with the socially constructed ideas of 'good' teacher, I was one of those who tries to meet with the criteria of being good. *'You, as a science teacher, teach science well to be a good teacher. Neither social issues nor critical minds are necessary.'* Within this conflict, science teachers could simply fall into a defensive type of teaching which tends to control classrooms by reducing rich real-world knowledge into school knowledge as an artificial set of facts and concepts (McNeil, 2000).

I also realized the importance of being a good and responsible citizen whose being and action are critically and mindfully aware of the relationships between education and society. With that regard, science teaching could not be only teaching the subject. There needed our critical minds and mindful action growing on social issues of science and technology, which I often missed for being faithful to the curriculum contents and skills. And yet, I did not feel comfortable or faithful in my self.

The notion of "live/teach divided no more" put forward by Parker Palmer (1998) emphasizes the integrity of pedagogy. It encourages us to teach and live with critical and responsible minds in the midst of the relationships between teachers' pedagogical beliefs and socio-cultural expectations. However, we often slip and display weak and passive minds in situations where institutional expectations pressure teachers' performance. Where the short-lived objectives and policies of the curriculum confuse us, we are also disoriented with new language and the rapid changes of the national curriculum. Within these conflicts we become teachers with "quick responsive attitudes or dragged compliance rather than proactive strategies to curriculum" (Brown & Jones, 2001, p. 15).

Within the pedagogical dilemmas that I lived through, I hope that I do not fall into defensive professionalism. However, as I try to stay empowered, encouraged, and undivided through my teaching, the dilemmas become more real and challenging. So the dilemmas are still ongoing and I appreciate the mindfulness that I learn from them.

Reflection on hermeneutic practice: The process of becoming

Reflecting on the challenges of STSE teaching through children's learning as well as the aporic moments of teaching, I realized that the research had been a journey of understanding my 'teacher' being in the midst of the relationships among children, curriculum, and social contexts. I attempted to reflect on the process of research in relation to the interactive questions of the researcher and the research texts. The following diagram represents the research process with children and the development of the researcher's self reflective questions (see Figure 10-1).

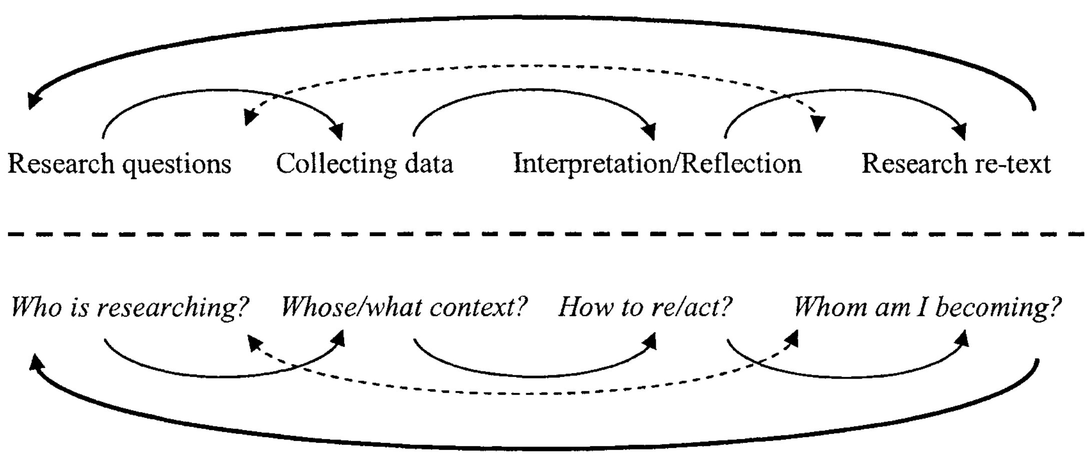



Figure 10-1. The interactions between the researcher and the researched

The research questions, data collection, interpretation, and reflection took place within micro and macro levels of the interactive loops portrayed in Figure 10-1. Mutual interactions among these dimensions were reflexively and reflectively intervening with each other through the research process. Underneath the dotted line across, there are questions about my self and my actions as researcher. The research procedure is explained above the line. With those inner questions, the researcher's research texts –

my previous experiences and understanding, the social realms of science curriculum, everyday relationships with children – were contemplated and examined with the research questions, data, interpretation, and reflective texts.

*The researcher who is questioned*

One expects to find answers to one's research questions through the application of appropriate research methods, and hopes to put forward significant reflections on the features of those researched. But what if the researcher finds that it is he/she who is being questioned and challenged the most? What if the research questions unexpectedly return and profoundly strike the researcher him/herself? Who is questioning and being questioned in that context? Who is the researcher and who is the researched?

Gadamer (1960/1999) explains that the hermeneutical logic of a question is always turning the questioner to the one being questioned. The research question returns to the researcher with other questions and puzzles and opens the research circle again. Therefore, hermeneutic research positions the researcher not as a knower who is seeking answers or discovering objects but as part of the question or situation itself. The researcher ultimately becomes a question.

*The process of becoming*

Throughout the research process, I understood that my being was also in the process of being questioned, challenged, and transformed. There was an endless interaction as I sought to understand the dynamics of the relationships between my being and the research texts. As the data were collected and interpreted, my own being was re-directed and re-situated with/in the research questions. The process of reflection provided a new beginning with new text as well as one step forward in becoming a mindful teacher and researcher. The hermeneutic process was inter-dialogical not only between the researcher and the researched but also intra-dialogical within the researcher's self.

This inter-dialogical mode directed me into a question about my previous teaching experience as a teacher educator. Reflecting on my struggles with STSE teaching through the research, I realized that my teacher education teaching was missing the profound understandings that I had now developed through the research process of the dilemmas of STSE teaching. I now realized more of what teachers would encounter. I felt irresponsible for my previous teaching without deep understandings of the difficulties likely to be encountered by a teacher. But, even after the research, I did not have solutions or answers to the difficulties yet. I only had the unsolved question of what I would do to cope with the pedagogical dilemmas in our minds.

When I came back to Canada from the research, I was asked to teach another teacher education as part of my graduate assistantship. However, I could not take the opportunity. With the unprocessed confusion and responsibility I was feeling, I could not teach, I could not speak in front of student teachers about STSE curriculum and teaching. I needed time to contemplate my confusion, and reflect on the questions, and possibilities of STSE teaching in today's classrooms. I decided to take time to develop inner strength so that I could speak out with confidence. It was a soul-searching time for which I am grateful. Answers are still incomplete and are coming to me as I am engaged in conversations with students to talk more openly about my experiences and their understandings of STSE and science curriculum.

## Reflection

Going through moments of aporia, I learned the importance and difficulties of pedagogical responsibilities for teaching with integrity. I learned humility through self-examination and reflection on pedagogical dilemmas. And I learned the difficulties of being a ‘good’ teacher, not only being equipped with knowledge and skills but also understanding and living with the questions of time and place in our life relationships.

With these experiences and challenges, I reflect on science teacher education next chapter. It will be a new hermeneutic opening for my research, which will develop its own path as time unfolds.

# VI

## REFLECTIONS ON SCIENCE TEACHER EDUCATION

This chapter has been developed as a thesis related to my concerns of STSE curriculum in science teacher education. It explores the potential of scientific literacy and STSE education through discussing the tensions of binary assumptions of knowledge and teaching in science teachers' understandings. Suggesting an ecological paradigm of science education, this chapter attempts to cultivate scientific literacy as embodied life knowledge.

# CHAPTER 11

## A SUGGESTION FOR SCIENCE TEACHER EDUCATION: SUMMARY THOUGHTS AND FUTURE PROJECTIONS

### Introduction

With my experiences and reflection during the research, my thoughts on teachers' pedagogical awareness and action became apparent and an intriguing matter for me in terms of STSE education. As we teachers seek for creative and authentic voices to cope with pedagogical dilemmas in the given situations of classrooms, curriculum, and society, it is teachers' action that can both timely and critically bring forth the ideas of scientific knowledge, lifeworlds, and citizenship for the 21$^{st}$ century. But on what basis do we make our decisions in the midst of the challenges of science teaching? How do we know if our decisions are responsible and pedagogical? To approach the challenges of teachers' decision making and action in science classrooms, it is vital to examine what and how we construct our understandings of science and education to become science teachers.

Based on those questions and my experience as teacher educator, I suggest this chapter as a thesis chapter with further reflection on the possibilities of scientific literacy and STSE teaching in science teacher education. To explore the potential of teacher education, I explore the notion of science teacher identity formation in an ecological paradigm of science education. In my discussion, I take into account two dimensions of science teachers' understandings which would challenge their practice; one is the nature of science and the other is the complex notion of teaching and learning. To do so, I will begin with the perspectives of complexity theory on learning which I find helpful to understand ecological, embodied process of knowledge making.

## The complexity of learning

There are certain images of traditional ways of teaching and learning. Teacher-learner relationships are top-down and the teacher (the knower) transmits knowledge as fixed, final product to the learner (knowledge receiver). The outcomes of teaching and learning are seen as predetermined, predicable, and linear products under the teacher's control. However, in classroom situations, learning and teaching is not reductive and linear. Learning outcomes are rather unpredictable because children are not passive receivers of knowledge. When I observed the children's discussions, children dynamically interacted with their peers and classroom surroundings. Their interactions often changed the direction of their discussion and my teaching creatively and differently from my lesson plans. The process of teaching and learning was not carried out as neatly as I planed.

To understand this notion of classroom situation, complexity theory introduces children's learning as complex phenomenon. In the complex system of human cognition, knowing is an emerging, self-organizing, and ecological process within the feedback of parts (individuals) and the whole (collectives of the environments – other subjects, artifacts and technologies, landscapes, learning environment settings, etc.) (Davis, 2004; Maturana & Varela, 1987). In this interactive feedback, there are two main ideas that I like to underscore in terms of ecological embodied learning. One is learning is embodied in learners' bodies. That is, children's learning is not conceptual only but embodied in learners' acting bodies. For example, children learned the meaning of recycling through observing, touching, feeling, thinking, and acting on it in this world. None of these can be separated from the unity of learning process. This idea supports the engagement of subjectivity in science learning, declining the separation between body and mind.

The other is learning is embodied in the collectives of the world, not only in individual learner. As parts are nested in the whole, co-structuring each other's being and action, each part, each knowing, and each action is interrelated with and responsible for the whole unity and vice versa. This understanding of the interrelationship of parts and the whole ensures our ecological and hermeneutic being and living in this world (Davis & Sumara, 2000).

There are some challenges in the notion of learning as complex phenomenon to be considered. One is the recognition of the uncertainty and creativity of knowledge and teaching. The challenge of the uncertainty and embodiment of learning process reopens the questions about epistemological assumptions, i.e., certainty vs. uncertainty and objectivity vs. subjectivity. Another is the teacher's role considered as part of a collective in a bottom-up and self-organizing learning system, not as the knowledge transmitter in controlled classrooms. This requires us to reconsider our position in the classrooms. These challenges will be discussed in teacher identity formation in the following section.

Teacher identity formation

In STSE teaching practice, science teachers encounter various impediments; lack of time, the shortage of teaching resources, the diversity of socioeconomic and cultural backgrounds of students, the difficulties of evaluation, teachers' unfamiliarity of STSE issues and so forth (Cailods, Gottelmann-Duret, & Lewin, 1996). Moreover, STSE curriculum requires value-laden and interdisciplinary approaches, challenging teachers' practice (Dillon, 2002; Eilam, 2002; Morito, 2002). In a society where the mode of competitiveness closely and greatly influences institutional ideologies and structure of science education, there is lack of interest and support on critical and issue-based science learning. These predicaments challenge our pedagogical decision making and often make teachers feel uncomfortable, hesitant, and passive in their practice of STSE curriculum.

However, there is another dimension of challenge that hinders teachers from implementing STSE curriculum. That is teachers' epistemological assumptions that subtly or actively create reluctance and resistance to STSE approach. Many of teachers' epistemological understandings and decision making are deeply rooted in assumptions of objectivity related in a positivistic understanding of science and knowledge. Some teachers regard STSE curriculum as being an objective and empirical way of science teaching. They are reluctant to practice what they see to be uncertain and subjective issue-based teaching. In this regard, the challenges of STSE curriculum are not only the matters of institutional support and disciplines, and not only of the constitution of science curriculum, but also about the epistemological basis that we hold to during our teaching. To discuss this notion further, I explore how epistemological understandings of objectivity and positivism could challenge pedagogical decision making and action in science classrooms.

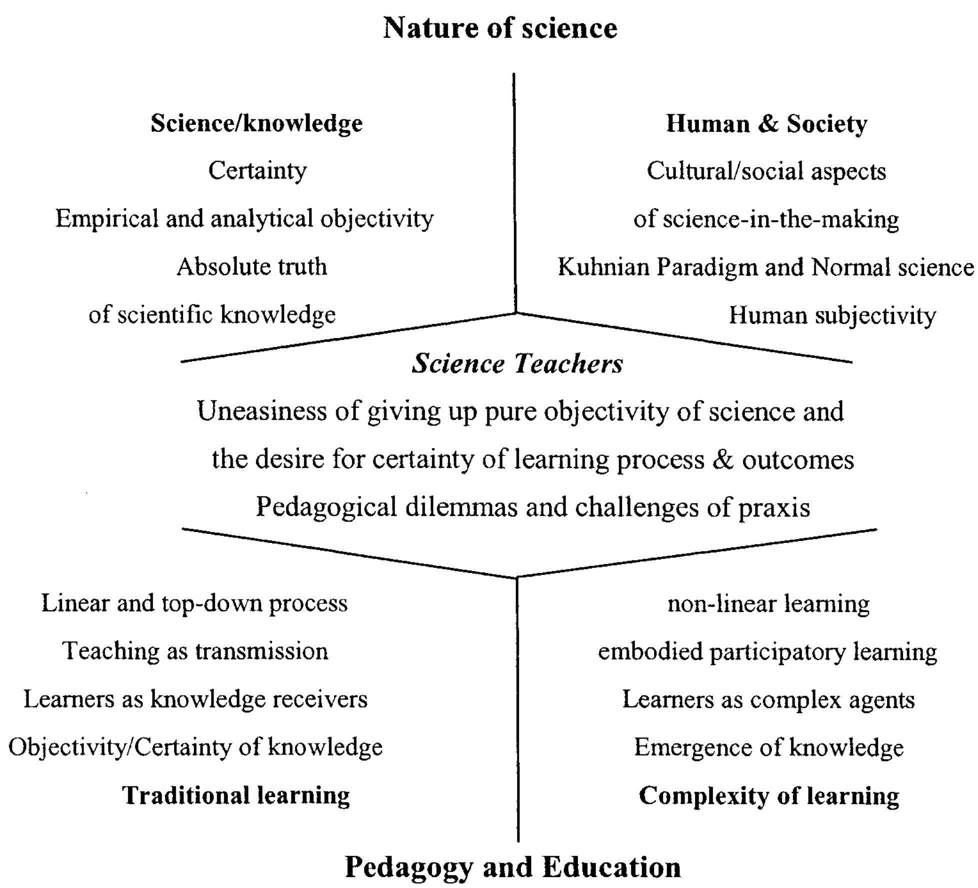
*Science teachers challenged*

When undergraduate students with their science background come to the education Faculty to become science teachers, their understandings of science have already been established concerning science as objective knowledge. Learning in the education Faculty, the students expect to receive teaching tools and strategies so that they can impart their knowledge to future students. Within two different domains of knowledge – science on one hand and education on the other, it is hard for some students to think of science teaching differently from the traditional views, that is, science as objective knowledge and teaching as transmission of knowledge. This binary notion is not much different among students whether or not their majors are in science.

Taking science education courses, students begin to encounter the questions of legitimacy of subjectivity in science as well as the challenges of uncertainty and nonlinearity in teaching and learning. Especially, for those students whose beliefs are in 'pure' objectivity of science, the engagement of human subjectivity and social aspects in science teaching is something that they wish to avoid. They think it is inappropriate or irrelevant for their future students' scientific knowledge constructions. I often heard my students say, "it is so hard to teach science differently because all my science courses were so rigid. We didn't talk, we just worked" or "I would not use free writing like poetry in my teaching because it is not scientific."

Furthermore, in the traditional ways of teaching, knowledge is assumed to be linear and transmissible, and thus, the learner's outcomes need to be certain and predetermined. Teachers who seek for certainty and authority of knowledge transmission could regard the notion of uncertainty of knowledge and outcomes as a failure of teaching. In this paradigm, controlled and top-down structures of classroom teaching are retained regardless of the complex dynamics of children's learning. Those tensions between the two dimensions of science and education (refer to the figure 11-1) are great challenges of epistemological assumptions and pedagogical action. The tensions between objectivity/certainty and subjectivity/uncertainty need to be thoroughly questioned to understand embodied and ecological science teaching. The figure 11-1 below shows how science teachers stumble upon confronting issues of scientific objectivity vs. subjectivity and reductive/conceptual vs. participatory pedagogy. In their understandings, science and knowledge are assembled to be objective and certain, however, they encounter the issues of subjectivity of scientific knowledge and uncertain process of learning science. Within this complexity of objectivity and subjectivity, science teachers experiences pedagogical dilemmas of their decision making on what and how to teach.

Figure 11-1: The challenges of becoming ecological science teachers



Science teachers consistently construct and transform their identities as science teachers as they undergo those tensions and challenges around the nature of science and teaching and learning. Knowing the uncertainty and nonlinearity of learning compels us to teach in innovative ways through attuning ourselves to situated contexts of time and place. To understand science teaching and learning not as a set of reductive procedure but as embodied phenomena through our living interactions is a challenging task. These ideas challenge teachers to examine their habits of mind and beliefs to understand a new dialogue of knowledge and science teaching.

Coping with binary understandings of science and education

Shifting science from objective science to embodied science is crucial toward a new paradigm of science curriculum in teacher education. There might be much tension and bewilderment emerging in our minds between objectivity of science vs. science as subjective human endeavors. But, it is not that we choose one aspect over the other but rather to understand both dimensions in harmony to strengthen one another.

To release some of the tension and resistance to human subjectivity in science education, I explore the understandings of embodied scientific realism in this section.

The discussion will continue to underline the possibilities of ecological science curriculum.

*Embodied scientific realism*

Introducing three levels of embodiment; physical-sensory motor, phenomenological, and cognitive unconscious, George Lakoff and Mark Johnson (1999) explain that scientific truth needs to be understood on the ground of interdependence of the three levels, not only phenomenology-first or science-first strategies. Human reason is embodied because our fundamental forms of inference arise from body-based forms. Human knowledge, thereby, is the result of our reason paired with subjective sensorimotor experiences of the world. When embodied reason recognizes its relations to physical worlds, human knowledge is possible in communal and stable realities.

Therefore, our cognition is embodied by engaging physical-subjective observations and inter-actions in order to know and explain the phenomena of the world. In this process, there emerges scientific knowledge which is embodied, inter-subjective, and inter-dependent with the environment.

> We have come to realize that the subjective dimension is always implicit in the practice of science. In a science of consciousness …some of the very data to be examined are subjective, inner experiences. To collect and analyze these data systematically requires a disciplined examination of first person subjective experience…this does not mean that we have to give up scientific rigor… When we speak of an "objective description" in science, we mean first and foremost a body of knowledge that is shaped, constrained, and regulated by collective scientific enterprise, rather than merely a collection of individual accounts…the intersubjective validation that is standard practice in science need not to be abandoned. (Capra, 2002, pp. 42-43)

Embodied scientific realism alleviates the tension between objectivity and subjectivity. It suggests that objectivity of scientific knowledge co-emerges and co-exists with human subjectivity in cognitive action. Validity and accountability of knowledge is fundamental characteristics of science, and yet it is possible by acknowledging its relationships to human beings, the observer and knower. In embodied scientific realism, Lakoff and Johnson (1999) emphasize that scientific knowledge indeed, provides us *valid facts and theories* of the world but also there is a need for recognition of human involvement and interactions in them. Embodied scientific realism helps us reconcile science, knowledge, human subjectivity, and the environment to the realm of scientific wisdom, which constructs stable and sensible understandings of scientific knowledge.

Lakoff and Johnson (1999) further distinguish embodied scientific realism from extreme relativism, but at the same time, they do not deny the relativistic aspects in embodied scientific realism.

> While it does treat knowledge as relative – relative to the nature of our bodies, brains, and interactions with our environment – it is not a form of extreme relativism, because it has an account of how real, stable knowledge, both in science and the everyday world, is possible. (Lakoff & Johnson, 1999, p. 96)

It suggests that science consists of both objective and subjective knowledge. In this understanding, we try to overcome the binary views of science and knowledge which have long been captured in the dichotomy of objectivity and subjectivity in our minds.

*Teaching and learning with embodied cognition*

The notion of embodied cognition also challenges us to examine our understandings of how we learn and teach science in classrooms. Understanding human cognition as embodied action, scientific knowledge is no longer seen as a separate, objective, and final product of knowing. Embodied cognition interprets teaching and learning not as the action of transmitting and receiving knowledge, because a cognitive process demands our participatory engagement in the environments to know and to learn (Abraham, 2003; Davis, 2004; Davis & Sumara, 2000; Maturana & Varela, 1987; Varela, Thompson & Rosch, 2000). Knowledge, therefore, emerges from dynamic and interactive relationships between the embodied learner and the environments, in other words, knowledge is neither fixed, nor terminal, nor linear (Bai, 2003; Morris, 2002). Learning with embodied cognition can help us understand the dynamics of classrooms, students' interactions, and creativity of knowledge emergence, which opens the possibilities of scientific knowledge in-the-making instead of ready-made science in textbooks.

As knowledge emerges through interactions, there are moments of collective learning that teachers cannot plan or predict beforehand. To my understanding, this collective mode of learning is an important notion in STSE teaching in terms of cultivating collective awareness and efforts among students. For example, in my study, children shared their experiences and stories of STSE issues. They collaboratively worked on their assignments. In the group activities such as newspaper making, children discussed, learned, and created their ideas among themselves. From interactions between parts (individual student) and the whole (collectives as group), children's learning was encouraged by one another. Especially, self esteem and motivation were also growing. Children were inspired to promote their behaviors with willingness and enthusiasm. They encouraged each other to act on what they learned. For example, they met in the morning and asked, "So what did you do yesterday to save energy?" Or they talked to friends, "Don't throw it there. That's recyclable." Then, they looked at each other and were laughing about their playful tone of voice. Children also complimented each other when they felt good about themselves doing the right things. I could feel that we were moving into something meaningful and someone proud. A lot of episodes happened beside content knowledge of curriculum or any forms of evaluation. And I questioned. 'Is it learning? Is it part of science education?' It was something that the traditional understandings of science teaching and learning did not recognize or value but it was truly happening among the children's understandings.

Individual's interactions stimulate the dynamics of the whole systems. As "the whole is greater than the sum of its part" (Kauffman, 1996, p. 24), the collective emergence of knowledge is powerful and enactive because the threads of relationships are together empowering our knowing. To my understanding, that is vital for scientific literacy as life knowledge and participatory citizenship. This understanding of the dynamics of embodied collectivity particularly helped me overcome my subservient attitudes toward STSE education.

## An ecological framework for science education

With the understandings of embodied science learning, I now expand my discussion on science education in an ecological framework. To understand the notion of ecological science education, I explain what I mean by the term, ecological in my work.

### *Ecological scientific literacy*

Ecological knowledge or ecological literacy has been broadly discussed in the public domains as well as science studies since issues around the environment and human lives have been raised in scientific, social, and political agendas (Barrett, 2001; Hart, 2003; Slingsby & Barker, 2004). Because the perspectives and interests of each domain vary in terms of scientific, ecological, and environmental knowledge, it is a challenging task to define the term, ecological. For instance, science studies such as biology, geology, or health sciences have been focused on ecology as scientific concepts and their tendencies became specialized and fragmented in their own domains (Barrett, 2001; Eilam, 2002). Social and cultural understandings of ecology focus much on holistic relationships amongst human values, life styles, economic and political structures, and sustainable environments. With these different perspectives of ecology, it is challenging to discuss what ecological literacy means in STSE education.

With this challenge, in order to expand the notion of scientific literacy in a domain of life worlds, I attempt to take the term, ecological as a way of knowing our relationship to the world. Being ecological means that we try to know how we are connected to the world and how we mindfully and responsibly act on our relationships. Through scientific knowledge, we understand scientific ways of our being and living to the world. The relationships are still there as the bases and results of our knowing. The position of being ecological is not opposed to being objective or empirical. Nor does it take entirely being subjective. It is rather a balanced position which does not support any extreme pole of science and the world. It reconciles dualistic understandings of objectivity and subjectivity, knowledge and action, and human and nature. The visions of scientific literacy are nested in these notions, that is, ecological scientific literacy.

In the grand scheme of life knowledge, ecological scientific literacy encourages us to know and learn science and technology in the context of modern time and place. It suggests that we learn the world through scientific relationships, not only by means of a theory or description of the world. That means when a new scientific theory or hypothesis is discovered and suggested, its explanation needs to take into consideration its life implications beyond an objective description of the phenomenon so that we can understand the meanings and projections of knowledge in our living relationships. This responsible action of science knowing is timely in modern society of science and technology. I attempt to illustrate my understandings of those relationships into a diagram as follows.

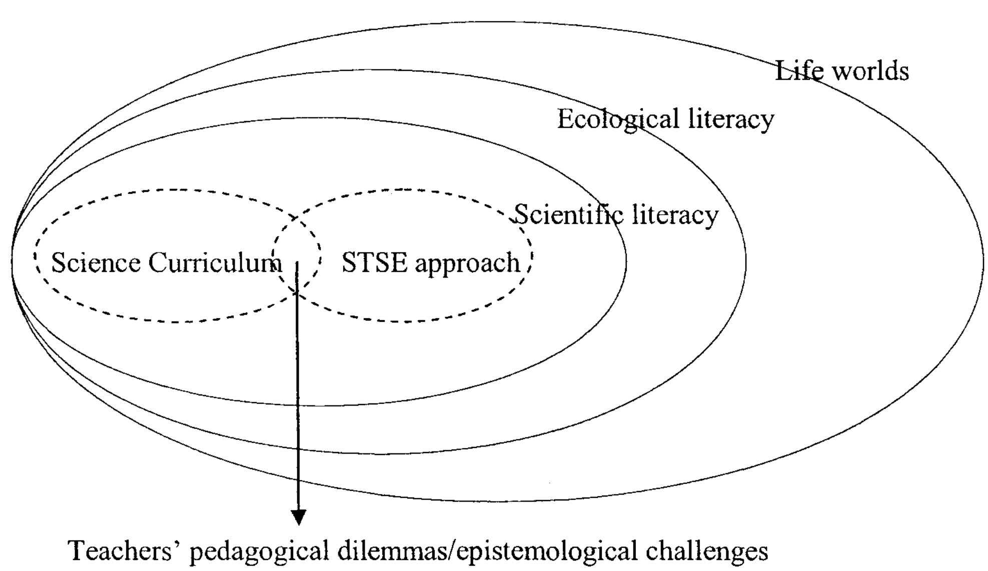



Figure 11-2. The paradigm of ecological scientific literacy

Science teaching is now nested in the interconnectedness of human life knowledge in my understanding. As our knowledge can never be isolated from the world, science education also understands the connections among scientific knowledge, children's learning, and societal enterprises with critical and ecological consciousness. With embodied human cognition, our teaching no longer allows us to separate students from their worlds. In ecological science curriculum, we seek for "the saving power" of scientific knowledge (Heidegger, 1954) in the relationships of science, technology, society, and the environment in modern time and place.

Contemplating on these thoughts, I talk about science teaching with student teachers. I strive to interweave my stories, questions, and struggles with theirs, hoping to construct the meaning of ecological science teaching together in our time. In our collective dialogues, there are our pedagogical dilemmas and struggles emerging. But as we encounter the struggles, we also understand there are the possibilities of ecological science teaching emerging through our dialogues. So we continue our story sharing to encourage each other and to teach and live together in contemporary science classrooms.

# A CLOSING REMARK

...

*What we call the beginning is often the end*
*And to make an end is to make a beginning*
*The end is where we start from*

...

*We shall not cease from exploration*
*And the end of all our exploring*
*Will be to arrive where we started*
*And know the place for the first time.*

From *Little Gidding* by T.S. Eliot

After the long journey of my research, I find my self standing on the smelly oily riverbank again, contemplating the relationships between the dying river and my science teaching in this time and place. The journey of questioning about scientific literacy and STSE education was indeed the process of learning about my being and action as teacher and researcher to be mindful, responsible, and integrated in a complex discourse of science education. And, with my understandings of the difficulties, humbleness, and patience of being and living with/in the research questions, it brought me back to the river where my questions have started. As the journey continues, the answers are still coming and I learn to remember the starting point with all these experiences and reflection that I have lived through.

The research opens a new path and now it is another beginning. As I walk on the path, I am becoming another question, another story, and another relationship of life. And I go on to open another dialogue.

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# APPENDICES

## APPENDIX A

Appendix A.1

***Question 1: Science and my everyday life***

- How do I experience science? Is my everyday life related to science? If so, in what way? If not, why?

Children's relations to science in their everyday lives (n=82)

| ***How do I experience science? Is my everyday life related to science? If so, in what way? If not, why?*** |
|---|
| **Yes,** because: (74.4% n=61) |
| By using technological products/innovations/appliances (52.4% n=43) |
| -There is no relation except using computers and electric home appliances (3.6% n=3) |
| -I am related to science using clock, TV, telephone, machines, computer etc. (48.8% n=40) |
| Land, my movements, things like those are all part of science (1.2% n=1) |
| Everything starts from science from the ancient history. (2.4% n=2) |
| My whole life is (surrounded by) science. (14.6% n=12) |
| Cooking (2.4% n=2) |
| My house (1.2% n=1) |
| **No,** because: (23.2% n=19) |
| No reason (14.6% n=12) |
| I won't become a scientist. (6.1% n=5) |
| No relation for now but I might be later. (2.4% n=2) |
| **Others** (2.4% n=2) |
| Science about the natural world is not boring but the science that we learn is not the same science out there. (1.2% n=1) |
| What we learn is not science in everyday lives or real life. (1.2% n=1) |

Appendix A.2

***Question 2: Science and Korean society/nation***

-Do you think the development of science is necessary for our society and nation?

If so, why? If not, why?

Table 8-2. Necessity of science and technology for society and nation (total n=85)

***Do you think science is necessary for our society and nation?***
***If so, why? If not so, why?***

**Yes,** science is very necessary for our society and nation because of;
(94.1 %, n=80)

-the development of the country; nation's economy (n=48)
-everyday life convenience including access to technological products (n=33)
-preparation for possibilities of wars (n=21)
-medical developments (n=14)
-better environment (n=5)
-food resources and products (n=4)

**No,** we have enough science and technology for today and more development would be dangerous for the future so we should stop developing them more. (5.9%, n=5)

(cf. The numbers of answers in the "yes" section are more than the total number of respondents because some students answered more than one.)

Appendix A.3

***Question 3: Science and the environment***

-I think the development of science influences the environment because....

-I think it does not have much relationship between the two because....

Table 8-3. Science, technology and the environment (n=86)

| ***How do the development of science and technology impact in the natural environment?*** |
|---|
| **It causes negative results,** because (87.2%, n=75) |
| -Cars and gas pollution (n= 70) |
| -Industrial garbage and swage (n=63) |
| -Constructing buildings and roads in natural environments and therefore natural habitats are threatened. (n=58) |
| -Wars and bio-weapons and so on (n=8) |
| -Noise (n=5) |
| **It does not have negative impacts,** because, (12.8%, n=11) |
| -It is human's responsibility (n=9) |
| -Home sewage and garbage (n=7) |
| -Science and technology will help to solve environmental problems (n=6) |

(cf. The numbers of answers are more than the total number of respondents because some students answered more than one.)

## APPENDIX B

**Interview 1 (Group A)**

| | |
|---|---|
| … | … |
| 미정: 너희들이 쓴 내용 중에서 과학과 전쟁의 연관성에 대해 쓴 사람이 많은데 왜 그런 것 같니? 특히 진이 쓴 내용을 보면 과학의 전쟁이었던 이라크 전쟁 이렇게 쓰여져 있는데 왜 우리가 과학과 전쟁이 연관 있다고 생각하니? | Mijung: I reviewed your drawings and writings and found out many people related science and war. Especially in Jin's work… You said that the Iraqi War was a science war. Why did you make connection between science and wars |
| 지: 미사일 이라든지 제트기 등이 날아 가는 것이 모두 과학의 없으면 안되니까요 | J: We can't really make missiles, jet engines and so on without science. |
| … | ….. |
| 미정: 요즘에 와서 과학과 전쟁이야기가 더 많이 나오는 이유는 뭘까? | Mijung: I have seen many of your drawings with wars. Why did war become an issue for your guys? |
| 도: 이라크와 미국의 전쟁 때문에, 요즘에 우리 많이 들었어요. | D: It is because there was a war between the US and Iraq and we have been hearing about it a lot these days. |
| 지오: 과학의 발전과 뭐 그런 것들을 위해서는 석유가 필요한데 이라크에는 석유가 많이 나니까 그런 거 때문에 | J: For the development of science or some other stuff, people would need oil and Iraq has it so… |
| 어: 그리고 북한 핵 문제 때문에 때문에도요. 사람들이 매일 얘기해요. … | E: There is also a nuclear weapon issue with North Korea. We hear it every day. |
| | … |
| 미정: 또 다른 어떤 과학에 관련된 문제 들이 많이 등장 했을 것 같아? 너희들이 쓴 내용 중에? | Mi: Are there any other issues related to science in you guys' drawings? |
| 모두: 복제인간, 유전공학, 인공 장기들, | Together: cloning, genetics, man-made organs… |
| … | |
| 미정: 그렇다면 우리가 과학을 반드시 | Mijung: Then can we view that science is |

| | |
|---|---|
| 위험하고 부정적인 것이라고 말할 수 있을까? 뭐가 과학을 위험하게 할까? | necessarily dangerous or negative? What make science dangerous? |
| 지: 나쁘기도 하고 좋기도 하고 | Ji: sometimes it is good and sometimes bad |
| 도: 꼭 나쁜 것 만은 아닌데, 나쁘게 사용하면 나쁘게 되고 좋게 사용하면 좋고.. | Do: it is not necessarily bad. If you use it in bad ways, it is bad but in good ways, it's good.... |
| 미정: 무엇이 잘못일까? | Mi: what would be the problem then? |
| 지아, 진보, 태호: 우리 인간들이, 사악한 마음을 가진 인간들이..네 그래요. 맞아요.... | J, B, T: It is we people who have cruel minds. Ya, I think so. I agree... ... |
| 진보: 복제 금지에 대한 내 의견을 그렸는데 끝까지 죽지 않은 일은 끔찍한 일이 될 것이니까요. | Jin: I put the ban on human cloning in my picture. It would be awful if we can't die at the end of our lives. |
| 지오: 인공 뇌로 인해 사람이 괴물처럼 변하게 되는 일이 발생할 수 도 있으므로 그런 일이 없어야 될 것 같아요 | Jio: I imagined an artificial brain and it would be terrible to turn to a monster. It shouldn't be happening.... |
| 민, 지: (그림을 보여주고 자신의 설명을 읽는다.) 로봇, 컴퓨터화된 인간의 생활에 대한 우려를 그렸는데요. | Min: (showing her drawing) I drew my concerns about robots and computerized human lives |
| 미정: 왜 나쁠까? 로봇이 다 해주면 편하고 좋지 않을까? 아무 일도 안 해도 되고 시키기만 하면 되는데. | Mijung: why is it bad? Wouldn't it be good if robots are doing all the work for us? We don't need to work. Robots will do everything for us. |
| 도: 편하고 좋긴 좋은데요, 로봇이 다해주면 로봇에만 의지하게 되니까, 그리고 로봇이 없어지면 우리들이 스스로 할 능력이 없어 지니까 안 좋아요. | Do: It would be good but it robots are doing everything for us, then we come to depend on robots and we can't do anything without them. We lose our ability of doing things. |
| 지오: 네. 인간의 능력이 퇴보하여 우리가 동물과 같은 생활을 하게 될 거 같아요. | Jio: yes, our capability will be retarded and we would have an animal-like life. |
| 미정: 동물 같은 생활은 어떤 건데? | Mijung: What do you mean by animal-like? |
| 민: 음...동물은 우리들처럼 기계도 못 다루고 또 그런걸 발명하거나 그런 것도 못하니까. | Min: urrr... animals don't have ability to do things that we can do...like using machines, inventing things like that. |
| 미정: 그렇다면 과학을 위한 우리의 자세는 | Mijung: what should our attitude toward |

| | |
|---|---|
| 어떠해야 할까? | science and technology? |
| 도: 우리들 스스로 깨어날 수 있는 과학을 해야 한다. | Do: we should do science with self-realization. |
| 지: 과학을 제대로 알아야 한다. | J: We should know science and technology right. |
| 미정: 조금 더 설명해볼래? 어떤 게 제대로 하는 거 같니? | Mijung: Could your explain more on that? What is the right way to know? |
| 지: 과학기술에는 좋은 점과 나쁜 점이 있다는 걸 우리가 알아야 해요. | J: I mean that there are some negative things in science and technology that we should know of. |
| 도: 제 생각에는 과학 기술공학이 잘 못 사용되었을 때는 우리 삶을 파괴한다는 걸 알아야 할 것 같고요, 그러니까... 우리는 그 점까지 깨달아야 한다고 생각해요. | D: I think we need to know science and technology can destroy our lives when it is used in wrong ways, so...I mean we should awaken ourselves to that point. |

# APPENDIX C

## The overview of Korean National Curriculum development

| | Period | Main focus | Science curriculum focus |
|---|---|---|---|
| Pre-curriculum period | Developed: 1946-1954<br><br>Implemented since: 1946 | -enumerating mandatory subjects and the content that need to be taught<br>-exerting to get rid of vestiges of Japanese imperialism<br>(cf. Korea was under the US Army control right after its independence from the Japanese Occupation.) | everyday practice and skills in natural phenomena |
| The 1st curriculum | 1954-1963<br><br>1954 | -subject-oriented education<br>-the first curriculum by the Korean National Education Board<br>-started to acknowledge the importance of practical aspects of education in people's lives | -spiral structured curriculum from low grade to high so that the contents could be overlapped and repeated for familiarity. |
| The 2nd Curriculum | 1963-1973<br><br>1963 | -life experience based education<br>-affected by the international flow, "The shock of Sputnik" and tried to focus autonomy, productivity and efficiency of school education | -The strong tendency of industrial structure and the progressive education were noticeable in the curriculum development.<br>-consistency and strong bases of scientific knowledge |
| The 3rd curriculum | 1973-1981 | -adopted J. S. Bruner's theory (knowledge structure | -scientific inquiry focused<br>-scientific concepts and |

| | | | |
|---|---|---|---|
| | 1973 | theory), however, tried to value Korean contexts more along with the international trends<br>-knowledge based curriculum | laws through discoveries and experiments focused |
| The 4th curriculum | 1981-1987<br><br>1982 | -realized that orienting only one trend or theory of education was not proper in Korean Education systems, thereby tried to balance out all categories above.<br>-focused on healthy and sound, aesthetic, capable, moral, and autonomous human beings | -critiqued the 3rd curriculum that it was only suitable for the students with scientific interests, not all students<br>-took account into learners' interest and ability<br>-Human based curriculum was balanced out with knowledge inquiry based curriculum. |
| The 5th curriculum | 1987-1992<br>1990 | -Integrated subjects for Grade 1-2<br>-developed learning practice books as a part of textbooks<br>-focused on healthy and sound, autonomous, creative, and moral human beings aesthetic, capable, moral, and human beings<br>-descriptive evaluation for Grade 1-2 adopted | - "Science for all"<br>-paid attention to "STS" relations but not enough research in the field<br>- Science and Mathematics integrated into one subject: Wise living in Grade 1- 2<br>-created exercise textbook for science<br>-more focus on hands-on activity |
| The 6th Curriculum | 1992-1997<br>1995 | -focused on healthy and sound, autonomous, creative and moral Korean citizens for the 21st century<br>-From textbook centered to the content of curriculum | -questioned<br>1) an appropriate amount of contents<br>2) effectiveness of teaching<br>3) focus on scientific inquiry |

| | | | |
|---|---|---|---|
| | | centered<br>-each school's and classroom's autonomy emphasized<br>-English subject | 4) everyday life topics<br>5) improvement of assessment |
| The 7th curriculum | 1997-recent<br><br>2000 | Catch slogan: *Autonomous and creative Koreans to lead the era of globalization and information in the 21st Century*<br>-Student centered (students as demanders of education)<br>-"self-initiating/leading learning"<br>-preparation for globalization and information era<br>-contemplation on the proper amount of learning (quality rather than quantity of learning)<br>-more strengthened in autonomy of the curriculum based on the school/classroom situation | -School teachers claimed that the content for each lesson was too much and difficult for learners. Also it was found that there was too much gap between Grade 6 to Grade 7 (Junior-high) and Grade 9 to Grade 10 (Senior-high) in the 6th curriculum so the revision was necessary.<br>-Less content and more consideration for learners' ability and the connection between elementary, junior and senior high levels were focused<br>-developed more advanced levels of learning activities at the end of each unit which expects teachers' autonomous considerations |

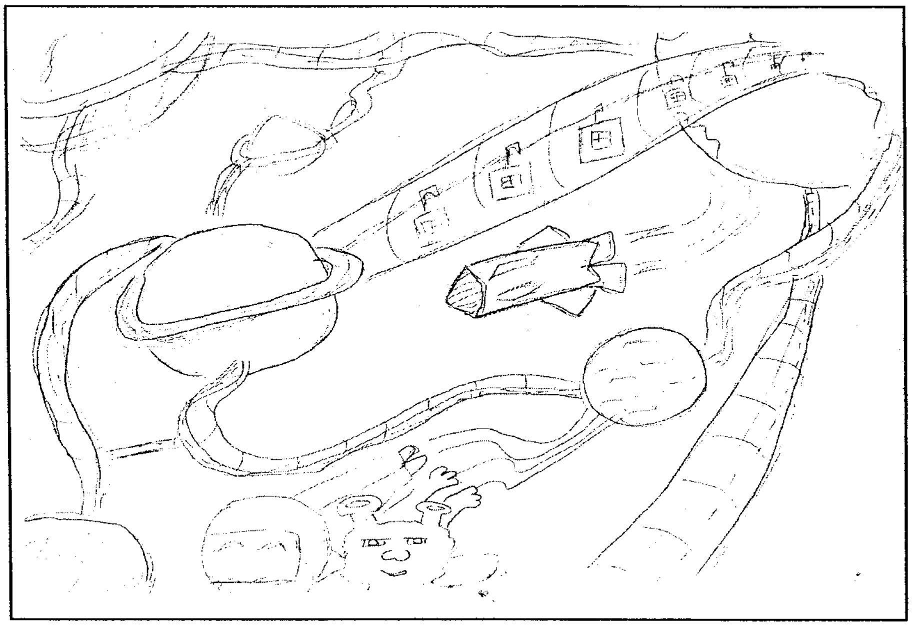
References:

The Ministry of Education and Human Resource (1999). *A Handbook of Elementary Curriculum I: An introduction.* Seoul: Korean Textbook Co.

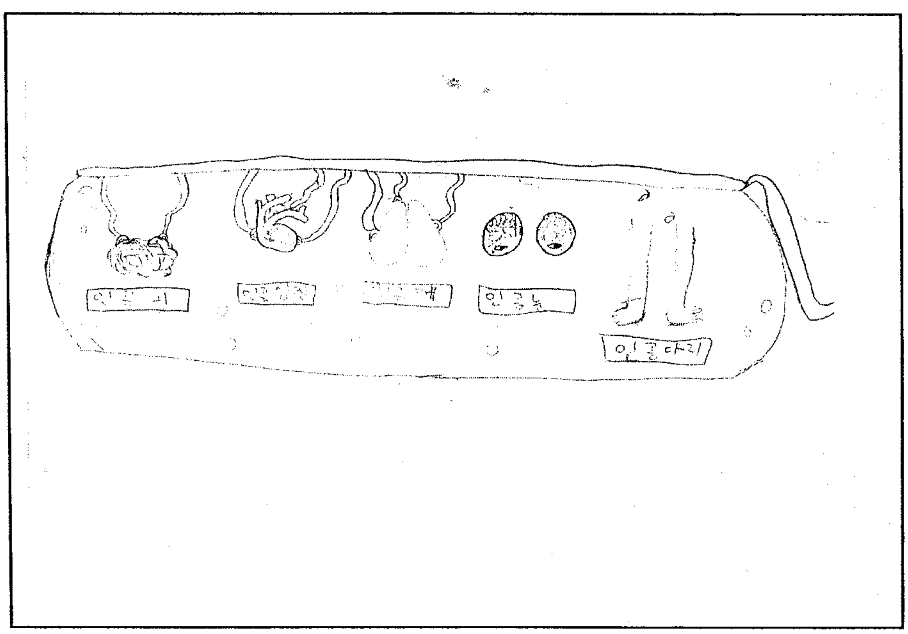
The Ministry of Education and Human Resource (1999). *A Handbook of Elementary Curriculum IV: Mathematics, Science, and Home managements.* Seoul: Korean Textbook Co.

## APPENDIX D

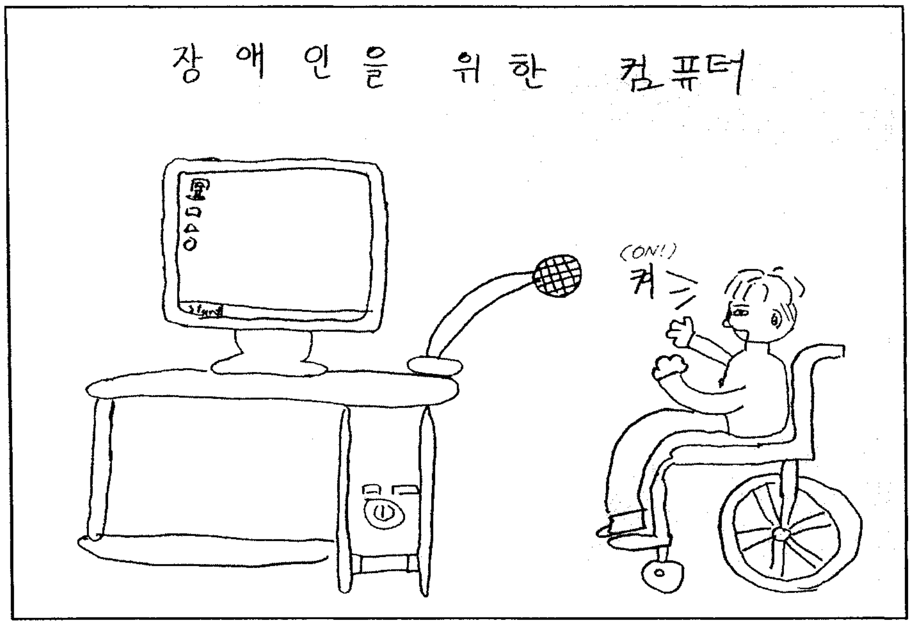
### Children's drawings



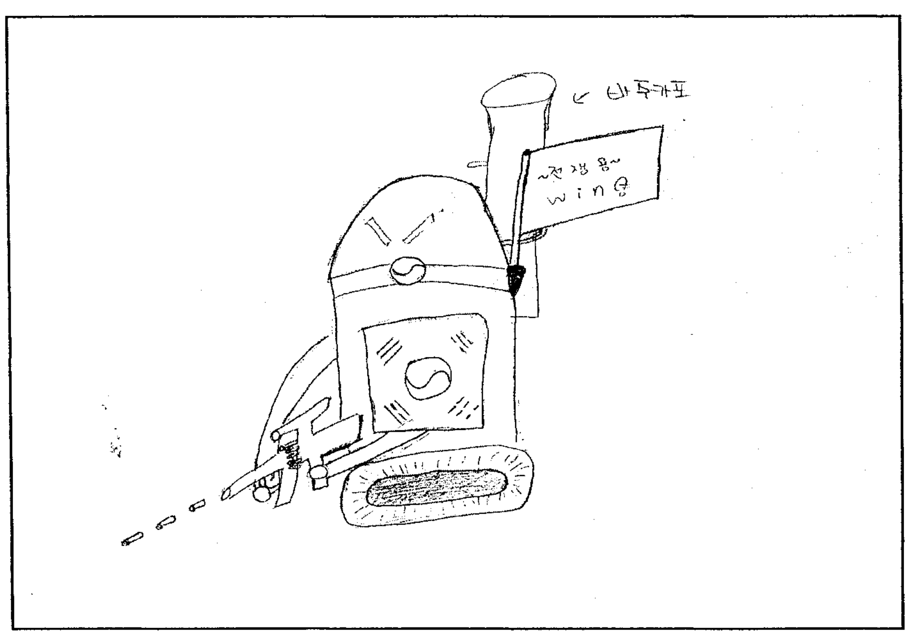
Space travel




Cloning: Artificial body parts (artificial brain, heart, lung, eyes, legs)




Computers for the disabled




A war robot

# APPENDIX E

**A vignette of classroom conversation**

September 24, 2003

....

Teacher (T): What has your group come up with as possible solutions to the environmental problems?

S1: We have some thing similar to other groups. But we have different ideas too. Throw garbage to other countries.

[The students are laughing.]

T: What do you mean?

S1: Sending garbage to other counties by ship, plane, or...

S2: That's ridiculous. That's very bad.

S3: But teacher, I heard that there are some countries which take garbage from other country. I think we can do that when we cannot solve the problem in our country.

T: Do you think it is fair?

S3: .... uh...but if there is enough land and ... they say yes.. then maybe it would be possible... I think... I am not sure... But how then did it happen?

S5: Yes, I heard that people could export garbage to some countries too.

T: What do you guys think? Any idea? Opinions?

S2: But who can be happy if other country dumps garbage in their land?

S4: Maybe a war would occur because they were mad.

S3: But it didn't happen. There was no war because of garbage, I think.

T: What if some country did it to our country? As many of you guys said earlier that the countries with more power interfere in our country's decisions on the nuclear weapons, what if those countries force us to agree to take their garbage? What if they suggest some money on that action? Would you agree? Or someone threw his/her garbage into your house? How would you feel? Would you feel nothing?

Some students: I don't want to take it....I won't.

T: Why? Can't the money do something good for us?

S: But if we had too much garbage, then we would have more pollution then, it would be hard to live in this place.

S4: It would be so dirty and smelly...

T: What other thing would you do or feel? Other opinions?

S5: I would be angry if other people throw garbage to me.

S6: I will throw more garbage to their place.

S4: See, it's almost war starting.

S6: I will go and talk to the guy not to do it again. And give the garbage back. Or I will ask some help to solve the problem. Maybe an NGO could help me. [They learned about the roles of NGOs in social studies class a few days ago.]

....

T: How about between countries? Can you guess what can happen between countries regarding to the garbage issues?

Students:...(pause)

T: Ok, now let's think about what would be the best way to solve this problem. I will give you 5 min. for group discussion.

(Group A)

S1: How could some country do such thing? I think it is so cruel.

S2: Yep. If some body did it to me, I would feel like revenging.

S3: But we have to find the best solution.

...

S1: Hummm, how about we put a garbage tank on the ocean?

S2: Or we can launch a garbage spaceship to the sky.

S3: No, that's impossible. Then we can have more pollution every where.

S2: Yes, it's possible. We can seal it. Then there is no harm.

S4: But which ocean and which sky? There are territories on the sky and ocean too.

S2: That's a good point. What should we do?

S1: Then maybe we, I mean each county needs to find solution to get rid of garbage on their own.

S4: How?

S5: In my opinion, ummm...every one needs not to waste their money and stuff. If we are frugal and saving every thing little by little, then garbage would reduce.

S1: Hey, but everybody wants to use a lot of money and want to buy new ones throwing old ones even though they are still ok. You, you (pointing at his friend, S4) bought new shoes a few days ago. Your old shoes were still good. You are the problem. Hahahahah! I am kidding. I am kidding.

S4: Hey, they were my birthday present.

S2: Who bought them?

S4: My mom.

S3: They are so cool. I asked my mom to buy a pair for me too.

(Conversation went off the topic.)

...

S5: Hey, guys, we have to finish this. What else?

S1: How about recycling?

S2: We are already doing really well on recycling. My home is a good example.

S3: Yes, my mom is always putting all recycling garbage in different boxes. So am I.

S4: Hey, is there any really good solution?

S5: See, I think, don't waste is the best, Don't you think? I am soooo smart...heheheheh...

S3: Hew... You fool...

S1: Yes, maybe that's the best.

S2: Anyway time is almost over. We need to summarize our group opinions.

S3: Yes, you write down all we talked about.

(Class)

T: Ok, let's share your ideas.

Group A: (They shared their ideas.)

Group B: We have "countries need to negotiate over the problems. And strong countries should not impose weak countries to take the garbage or any thing like that."

Group C: We have "all people in the country voluntarily clean and treat their own garbage so that there would be no need to worry about it. We also have we can get some help from the UN to solve the problem between countries.

Group D: Our group talked about how we can solve the problem between neighbors. We have "We should have a good neighbor-friendship so that we can help each other. We can clean our neighborhood together or take turns. We should not put our responsibility to others and.... Urrr, ye, don't do harmful things such as throwing garbage to others' places." (another student) And we have said that we need to develop more technology to mash all the garbage to dust or make something useful.

Group E: Our group has similar ones. We have "Immense garbage machines can eat up all the garbage and there are no tracks of garbage."

Group F: We have some thing like Group A. Like Nanjido (one of the largest landfill of garbage and now a park was built up in that area in Seoul.), we can find a place to bury garbage and use the land for some thing good.

T: Ok, thank you for all your good work. You guys talked about Nanjido, burying garbage, technology, helping each other and so on. Now I will give you an assignment. You can think about it at home and talk about it next time. What is going to happen when we can't develop technology in near future, we would bury all the garbage on the ground and all the land was getting filled by garbage and there would not be enough land to live? What kind of problem would we face? If it's the case, what would be the best solution for this problem? You can search some information on Nanjido too. Then you think about the balance of ecosystems that we have learned. Ok, good, everyone, class is ended here. Take a break.