Investigating Sixth Graders' Understandings of Science-Technology-Society-the Environment (STSE) Relationship and Challenges of STSE Teaching

Kim, Mijung
(Seoul National University)

6학년 아동들의 과학-기술-사회-환경(STSE)의 관계에 대한 인식과 STSE 교육의 과제에 대한 고찰

김미정
(서울대학교)

국문초록

과학교육에서는 과학과 기술과 관련된 사회적 또는 환경 문제의 증가를 더 이상 간과할 수가 없게 되었고, 이로 인해 과학-기술-사회-환경(Science-Technology, Society-the Environment: STSE)교육을 통한 실천적 과학 소양의 중요성이 대두되고 있다. 본 연구는 환경 내용을 다룬 초등학교 6학년 2학기 과학 단원, 3. 쾌적한 환경을 학습하는 과정에서 환경 중심 STSE 교육의 어려움과 그 가능성에 대하여 고찰하고자 하였다. 초등학교 6학년 두 개의 반 아동 86명은 단원 학습에 참여하는 동안 설문, 그리기와 쓰기, 면담에 참여하였다. 수집된 자료는 아동들의 과학-기술-사회-환경의 관련성에 대한 인식과 과학 지식의 실천적 소양이라는 측면에서 분석되었다. 결과로는 첫째, 과학-기술-사회-환경의 관계에 대한 아동들의 인식은 현대 사회가 가지고 있는 가치관과 복잡하게 얽혀 있었으며, 이 안에서 과학/기술의 발전은 사회 발전과 환경 문제의 두 측면에서 다소 상반적인 관계를 보였다. 둘째, 환경 문제에 대한 아동의 인식은 높은 반면 실천적 소양의 측면은 상대적으로 낮았다. 셋째, 과학-환경 지식은 환경 문제 인식과 문제 해결에 그다지 영향을 미치지 않았다. 이러한 결과들을 바탕으로 본 논문은 실천적 과학 소양을 위한 과학-기술-사회-환경 교육의 문제점과 어려움에 대해 논의한다.

주요어 : STSE (과학-기술-사회-환경) 교육, 소극적 인식, 현대 문화의 영향, 과학적 소양

I. Introduction

In recent era, there is an increasing number of social and environmental issues related to modern science and technology such as biotechnologies, public health, and environmental destruction. Science educators claim that young generations would encounter more complicated issues of science, technology, society and the environment in future society. Therefore, there need considerable efforts to provide students with opportunities to understand the complexity of the issues and the process of decision making and taking action (Hodson, 2003; Hurd, 2002). In the complex relationship of science and human lifeworld, the role of scientific knowledge for sustainable future has been discussed in science education (Colucci-Gray *et al.*, 2006). With this increasing need of thoughtful decision-making on controversial socioscientific issues in modern society, scientific literacy for citizenship has been taken as one of the main goals of science education. As a way of promo-

2007.5.21(접수), 2007.7.3(1심통과), 2007.8.3(최종통과)
E-mail: mijungkim@snu.ac.kr(김미정)

ting scientific literacy for citizenship, Science-Technology-Society (STS) education has been widely practiced addressing value-laden socioscientific issues in classrooms (Aikenhead, 1994; DeBoer, 2000; Galbraith *et al.*, 1997; Hodson, 2003; Hurd, 2002; Kolstø, 2000; Roth & Desautels, 2004; Yager, 2000; Willinsky, 1998; Zeidler *et al.*, 2005; Ziman, 2000). With concerns about environmental destruction in modern world, some science educators have advocated the term, STSE (Science-Technology-Society-the Environment) education to emphasize the importance of the environment (Pedretti, 2003; the Council of Ministers of Education, Canada, 1993). To focus on environmental issues, this paper purposely uses the term, STSE instead of STS.

There have been critiques that the practice of STSE education has been struggling in real classroom situations and the evidence of its effectiveness has been lacking. That is because STSE education has long been regarded as peripheral as opposed to mainstream content-based curriculum (Aikenhead, 2006; Jenkins, 2000; Roberts, 1995). Despite these struggles, STSE education has consistently thrived to bring forth social and environmental issues to cultivate scientific literacy in real life situations (Driver *et al.*, 1996; Hodson, 2003; Hurd, 1998; Kolstø, 2001; Kozoll & Osborne, 2004). This effort has brought many possible visions of STSE approach which can support a sustainable world (Aikenhead, 2006; Pedretti, 2003).

Along with the discussion of STSE around the world, this study questions the issues of STSE education in terms of participatory roles of scientific literacy with concern of children's STSE knowledge. Scientific literacy in school science has focused on scientific content knowledge and skills, not much on the practice of knowledge and skills in complex life situations. The gap between knowledge and life implication has long been discussed in the discussion of scientific literacy. This gap leads scientific literacy to not participatory but conceptual knowledge separated from real life world. If scientific literacy refers to the knowledge which mainly looks at content-based objective knowledge, 'participatory' scientific literacy emphasizes the praxis of knowledge which is embodied in decision making process and taking action in life situations. To overcome the separation between children's lifeworld experience and science teaching, this study attempts to examine children's understandings of the relationships among science, technology, society and the environment. Through teaching ecosystems and the environment in the manner of STSE approach, this study probes conflicts among STSE and the gaps between knowledge and action in children's understandings. Based on children's experiences, reflection, and action about environmental issues, this study argues that STSE teaching needs to examine the complexity of values in modern lifeworld and the gap between knowing and doing in terms of the cultivation of participatory scientific literacy.

II. The Process

1. Research Questions

Emphasizing environmental issues, this study attempts to look into children's understandings of STSE relationships. To understand the complexity of children's knowledge and practice, it also concerns of how children encounter environmental issues in everyday lives and how they take action according to their understandings of the issues. The specific research questions are as follows.

a) How do children understand the relationships of science, technology, society and the environment?
b) What remains in the gap between children's awareness and their actions in terms of environmental issues?

Through investigating these questions, this study develops a further discussion on the challenges of STSE teaching.

2. School Context and Participants

The study took place in a public elementary school in Seoul, Korea. The school is located in a residential area. The community consists of high rise apartment complexes, condominiums, and townhouses. Children's everyday environment is modernized, technologically advanced with high population density. 86 sixth graders (age 11~12, 44 boys and 42 girls) from two classes participated in the study for four- month period. More than two thirds of the participants were born in Seoul and have never lived outside of the city. The socio-economic level of the children's homes is middle-class and relatively stable. According to classroom teachers, most students were well-supported by their parents in terms of school supplies and resources, internet access, homework aids, and so forth.

The unit; 'Pleasant Environment,' taught in this study 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.

This unit contains scientific knowledge and STSE issues, especially environmental issues and hence was appropriate for the research questions. With those topics as the content of the explicit vision of scientific literacy mandated by the curriculum above, this study attempted to examine possibilities for cultivating participatory scientific literacy, that is, a notion of scientific literacy that includes lifeworld connections and a view of scientific literacy as embodied knowledge. These ideas value the integrity of knowledge and action, the interrelatedness of being and living, and responsible participation.

The unit was taught by the researcher, following the regular science curriculum. It was because the research intended to ponder difficulties and challenges of STSE teaching on teachers' regular basis. That is, this study is not a research which looks for effects of purposely developed teaching programs but for attending and analyzing the situations of STSE learning and teaching in regular classroom settings, which can make the discussion of STSE education more realistic and relevant to science educators.

3. Data Collection and Analysis

The use of multiple sources and methods of data collection builds up the strength (dependability, confirmability) of the research to avoid misunderstandings of the research 'texts' (Geelan, 2004; Lincoln & Guba, 1985). That is, the research questions were approached with different methods in different situations so that the data can be collected from diverse resource pools and the meanings of the data can be saturated in the thematic structure of interpretive circle, which allows research data to be interpreted with the coherence and contingencies of contexts (Gallagher, 1997). To investigate the research questions and establish multiple forms of data collection, various methods were utilized such as drawing activity, interviews and questionnaires to construe children's understandings of science, technology, society, and the environment (STSE) relationships. Children's conversation and reflective writing also provided evidence that helped to understand the trajectory of students' understandings of STSE. The complementarities of different methods supported the strategic reliability of interpretation. The main research methods and strategies are explained in detail in the following section.

1) Questionnaire

Questionnaire was given 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. The questionnaire was open-ended to examine children's ideas on Science and my everyday life, Science and Korean society/nation, Science and the environment. Children's answers were taken into consideration to assist in the interpretation and the development of themes in relation to children's understanding and today's world of science and technology.

2) Drawing

Children's drawings provide a means to project their imaginary ideas into a medium of visual communication and representation and 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 part of children's interpretation of their society and culture, hence, its contextual and embodied nature is valuable to approach research questions (Cox, 2005; Mathews, 2003; Ring, 2001). Children were given the following question and asked to produce drawings: "How I imagine future society's relationships with science and technology?" Students were then asked to write a brief explanation of their drawings. Follow-up interviews and discussions were carried out with two groups of 5~6 children for about 30 minutes each.

3) Interview

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. There was one focus-group of 8 students whom I interviewed 5 times throughout the research and other 4 groups only once. Interviews were open-ended and informally structured; however, topic- related questions and comments by the researcher guided children to focus on topics. All of the interviews were transcribed, coded, and selected according to similarities and differences for data analysis.

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. Peer discussions and debriefing took place to discuss the raw research data and tentative interpretations to reinforce the meaning of the research texts (Lincoln & Guba, 1985). One elementary teacher who was the homeroom teacher in the research site and one instructor at university were engaged in peer review process. I shared and discussed the data and interpretation so that the analysis of data could be reflected and triangulated. We discussed our interpretation through face-to-face and email interactions.

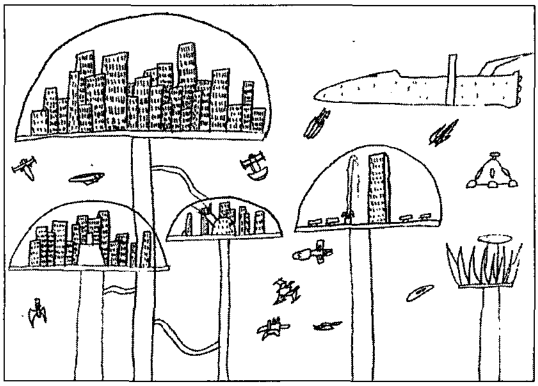
III. Research Findings

Research findings are explained in three dimensions as follows: (1) children's complex understandings of the environment in the relationships of STSE, (2) children's passive awareness which means the separation of scientific knowledge and action, and (3) separation between scientific knowledge and STSE contexts.

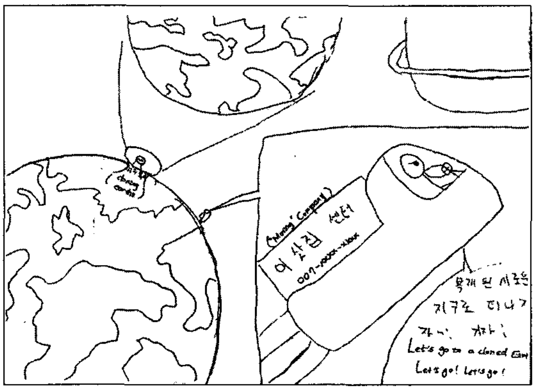
1. Children's Complex Understandings of the Environment in the Relationships of STSE

Children's understandings of science and technology showed opposite aspects of its relationships to the society and to the environment. In their understandings, science and technology has positive and necessary relationship with societal dimensions in terms of economic development and civilization whereas its relationship to the environment is negative. The majority of children in the study envisioned science and technology as having unlimited capacities of solving human problems such as overpopulation, energy shortage, incurable diseases, environmental degradation, and so forth. 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. For example, separating humans from the world that we live in today, their solutions are seeking for another place in space (Fig. 1a and 1b) or undersea as possible solutions to overpopulation and pollution (see Fig. 1c).

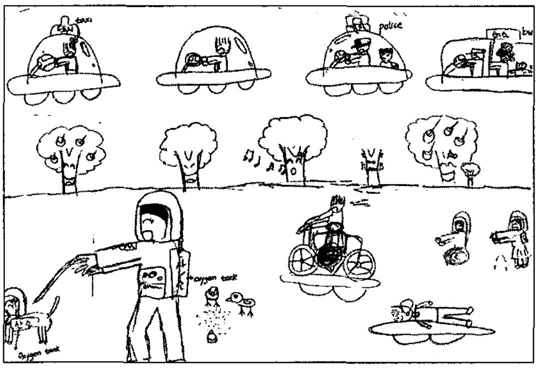
In children's understandings, there is children's concern about insecurity around science and technology



a. 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).



b. 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).



c. Soojin: 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).

Fig. 1. Examples of children's drawings

in future environment. Some of children's drawings indicate that modern science and technology is no longer only a hopeful fantasy, but it has also resulted in concerns 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 1). In the Table 1, there are positive aspects of science and technology above the dotted line and negative ones below the line. However, even in positive aspects, some children explained the reasons that they came up with these ideas were to solve problems such as pollution or lack of energy.

In contrast to the enthusiastic ideas of scientific and technological innovations, children also expressed contradictory understandings of science/technology toward environmental issues. They attributed environmental destructions to the outcomes of scientific and technological developments. They explained:

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

Contents of children's drawings	n	%
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
Machines eliminating pollution	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

> There ... are huge problems like a landfill project on the West coast ... It destroyed the ocean ecosystems around that area ... I think science and the environment have very close, harmful relationships. (Girl, age 12)

> 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. (Boy, age 11)

> It is true that gas or sewage ... cause environmental problems. That's true, but now factories are trying to reduce pollutants. (Boy, age 12)

87.2% of children (n=75 out of 86) answered that the development of science and technology causes harmful impacts on the natural environment whereas 94.1 % of the children (n=80 out of 85) responded that science and technology are necessary for the development of the nation and welfare (see Table 2 & 3). They further indicated that the environmental problems are inevitable byproducts of the nation's economic growth and technological progress.

> It can not help but destroying a little bit of the environment to be strong nation (girl, age 12).

> I think the development of the society is more important than the environmental conservation (Boy, age 11).

In the complex understandings of STSE relationships, the collaboration of STS for economic development is more valued than environmental dimension. To some extent, children's ideas around science, technology, society and the environment represent spread 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 (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. "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 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.)

Table 3. Science, technology and the environment (Total 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.)

2. Children's Passive Awareness Which Means the Separation of Scientific Knowledge and Action

Many children (76%) in this study experienced environmental destruction through first hand experiences. The children expressed regret and disappointment through a number of visual images of pollution with garbage problems, car gas, dead fish, and constructions in mountains as lived experiences. With their awareness as a context of knowing, 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 pointed out their reasons as follows:

During the interview, children described their reasons more in details.

> Now I am only 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)

Table 4 Barriers of action (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%)

> If we really want to protect the environment, we have to live like people in the 16th century. That's impossible. We shouldn't use shampoo, cars, … almost nothing … How can we live like that today? (Boy, age 11)

Children take a position 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.

As Barnett at al.'s urban ecology field study (2006) addresses, it is crucial that children recognize that connection to the environment they live in as theirs. They argue that this way can develop children's environmental stewardship. However, many children in modern world perceive the environment as place of others such as animals, forests and streams (Shepardson, 2005). They do not understand the city as part of ecosystems. When children understand the environment as others' place, their action is not belonging to the environment. Teaching ecosystems and the environment should be careful not to add another isolation of the environment as place for natural components separated from urban environment; however, this separation is a typical way of teaching ecosystems and the environment in science classrooms.

3. Separation between Scientific Knowledge and STSE Contexts

In this study, children did not bring about their scientific knowledge of ecosystems and the environment in interviews, discussions, or written texts when it comes to reasoning and decision making on environmental issues. For example, when it comes to environmental problems, children's ideas tended to align with moral or aesthetic standpoints. Scientific concepts they learned did not appear in understanding issues and attitude toward the environment. The frequency of children's explanations and responses to environmental issues, especially pollution and conservation during interviews and writings can be summarized as follows.

The following is an example of class discussion on pollution and responsible action, differentiating nature and city environment.

T: What is an environment?
S1: That's where animals and plants are.
S2: mountains? Rivers?
S3: rural areas. When I visit my grandmothers, there are lots of environmental things.
...
T: Why do we need to protect ecosystems and the environment?

Table 5 Children's responses to environmental issues (Total n=65)

Children's responses to pollution and environmental protection
Pollution is not good for life and health. (n=24, 36.9%)
Pollution disturbs my feelings. (n=16, 24.6%)
We need a place to relax. (n=11, 16.9%)
It is sad that animals are threatened/getting extinct. (n=5, 7.6%)
Environmental protection is a right thing to do (n=4, 6.2%)
Nature is scared, so to be protected. (n=2, 3.1%)
Carbon dioxide causes global warming. (n=2, 3.1%)
Polluted water gets into the water cycle. (n=1, 1.5%)

S1: That is a right thing to do.
S2: Harming animals is not ethical.
S3: It destroys the beauty of nature.
S4: We can't find a place to relax if not. We cannot be healthy in polluted environment.
T: In what kind of process are ecosystems, air, streams etc. polluted or harmed?
S2: We throw garbage.
S1: because we are not careful enough to protect the environment.
S3 & S4: *using lots of fuel and trees*
T: Do you think in what way what you learned in science class is related to environmental issues?
SS: Ummm... (27 second pause)
S3: I don't know...
S4: We know where animals live and eat...
S5: food chain and food pyramid
S1: ya.. That's about the environment.

This conversation took place during learning the contents of ecosystems. The children's answers were related to ethical, emotional or anthropocentric understandings. In terms of environmental conservation and pollution, children's ideas or comments rarely included scientific knowledge such as water/air circulation or energy flow in ecosystems. Children seemed to depo-

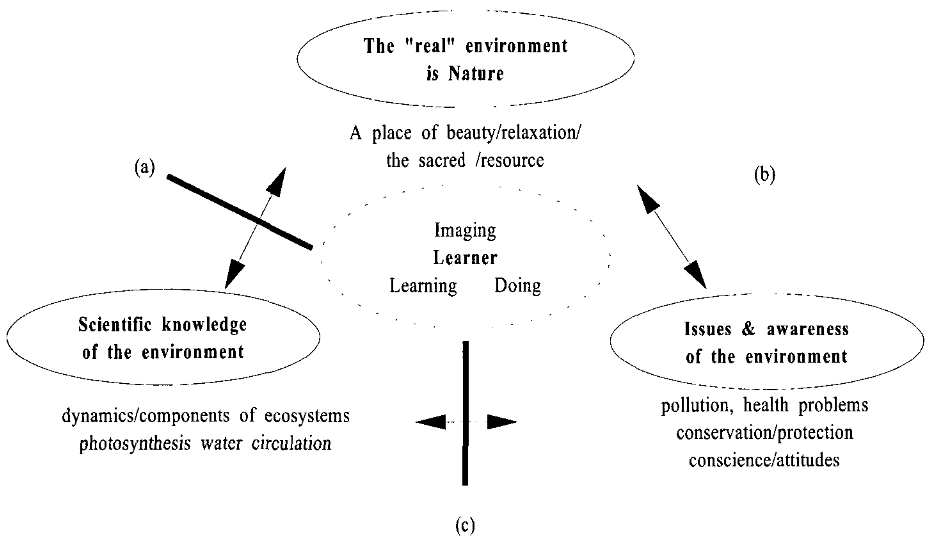


Fig. 2. Children's understandings of the environment.

sit the different ideas of the environment in different domains. Summing up their understandings of the environment, I provide the following figure.

Line (a) indicates there is little evidence of connection/interaction between students' understanding of Nature and scientific knowledge, the line (b) is more evidence of interaction between the understandings of Nature and socio-environmental issues, and the line (c) is little evidence of connection/interaction between scientific knowledge and socio-environmental issues. Some researchers indicated that there was no strong evidence that adults, even scientists and professors in sciences utilize scientific knowledge as the main source in decision-making in science-related circumstances in their daily lives (Aikenhead, 2006; Bell & Lederman, 2003). Along with those researches, this study shows that children's scientific knowledge does not play an important role in the majority of children's everyday decision making. This notion gives rise to questions of what it mean teaching STSE issues in science classrooms and what scientific knowledge has to do with decision making and action. These questions will be considered later in discussion section.

IV. Discussion

With the challenges of separations of human nature and knowledge action in children's understandings, promoting scientific literacy in real life situations is not an easy task. Considering scientific literacy in relation to responsible decision making and action on socio-scientific issues in science education, STSE teaching requires interdisciplinary approach to understand participatory roles of knowledge. This challenges science teachers to make pedagogical decisions in terms of relationships of content knowledge and societal action. It is not only a matter of teachers' commitment to STSE teaching but complex issues with social and epistemological assumptions that we live with in today's world.

However, some could argue that we should not teach STSE issues at elementary levels because they are too young to learn the responsibility of knowledge and action on STSE issues. Further, addressing STSE issues might give students negative perspectives of science and technology in early ages. They might say that it is inappropriate to concern about the development of participatory and responsible scientific literacy in grade 6 (age 11~12) science classes. However, this claim cannot be justified where there are concerns about children's science learning that already shows the complexity of children's STSE understandings and disconnected action from what they learn at school in this study. This aspect gives rise to pedagogical questions how much longer we could ignore what children's stories have put forward to us. To clarify, however, I do not argue that we need to guide students with controversial issues of STSE which are not yet experienced in their lifeworlds. This might give students negative and distorted ideas of science learning. However, when children bring about their lived experiences and stories of science, technology, society and the environment in class, science teachers can no longer ignore their concerns in terms of the connection of science and real life world situations. This respect leads me to questions of what and how this study is meaningful to the discussion of scientific literacy in contemporary society for a sustainable world. I will discuss: a) the conflicts of modernist values and sustainability in children's understandings, b) the isolation of scientific knowledge, and c) the negligence of disintegrated knowing and doing in science classrooms.

Firstly, science and technology is no longer separated from the sustainability of the environment. This means that science teaching needs to concern about conflicts among scioscientific, economic and environmental dimensions in children's understandings so that they as citizens will be able to practice science and technology in problem solving. Often times, internal factors such as values, judgment systems, and social interactions influence children's decision making more closely than conceptual knowing (Fisman, 2005; Kollmuss & Agyeman, 2002; Zeidler *et al.*, 2005). This suggests what children value closely influences their decision making. When children value economic social development more than environmental sustainability, their decision making and action tend to be oriented toward the latter. This tendency is seen not only in children's understandings but the world that we live in today. As the utopian expectation of technoscience has grown as a "characteristic subculture of the general culture of modernity around the world (Ziman, 2000)," children's and adults' imagination of science is also constructed as a means of developing an overly positive future (Mander, 1996). In this value system, the enthusiasm of technoscience and economic development verses the responsibility of decision making and action for sustainable society can be a critical conflict in terms of practicing scientific literacy for citizenship. This issue challenges deeply the relationships among science, technology, the environment and modern culture, requiring consistent interdisciplinary efforts in teaching ecosystems and the environment in modern science teaching.

Secondly, it is to question how we understand the lack of the engagement of scientific knowledge in socioscientific or environmental issues. If science teaching needs to develop sustainable practice of science and technology, scientific and technological knowledge needs to be understood in the process of understanding and solving environmental issues. However, in this study, children's understandings of environmental issues are not much related to scientific knowledge they learned in science classrooms. They posited environmental awareness, knowledge of the environment, responsibility and emotions in separated dimensions of knowing. In STSE classrooms, it is a typical error that socioscientific and environmental issues are addressed as add-on or peripheral dimensions. Science teachers teach scientific concepts as main text and STSE issues as optional stories. Yet, when scientific knowledge is not understood in relation to environmental issues, it is hard for learners to understand the critical roles of science and technology to solve environmental problems. This means the role of scientific literacy would be separated from social practice and responsibility.

Lastly, the gap between awareness and action in children's knowing should be taken into consideration in terms of STSE knowledge development. As scientific literacy for citizenship as cornerstone of science education in the 21st century has argued the importance of citizenry participation through scientific knowledge, it is critical that knowing and learning is connected to taking action. This leads knowing about socioeconomic and environmental conflicts needs to bring forth action with responsibility and ethics. Relying on simplistic linear cause-effect model of learning, value-laden STSE education has not much taken into account complex interactions among awareness, critical thinking, decision-making, and taking action. Yet, science educators cannot expect when knowledge and awareness is learned, attitudes and action will be followed. Such reductive models cannot cultivate children's ethical action and behaviors on STSE issues as illustrated in the children's stories.

Given that there remain some challenges of STSE education discussed above, STSE educators need to contemplate on concrete strategies to bring forth the issues of STSE and the connection of knowledge and action. First, in science classrooms, it can be recommended to explicitly discuss the roles of science and technology in modern society. That is, there needs to be discussed what would be both positive and negative aspects of modern science and technology and how human agency can determine its outcomes by applying scientific knowledge and skills. This can also emphasize the importance of decision making and the responsibilities of human action in STSE issues.

Second, it is also important for teachers to emphasize the importance of actions following awareness on STSE issues in science classrooms. As science education has attempted to deliver/present the issues without looking into how knowing those issues can bring about children's action and behaviors, it is necessary to shift the paradigm of separated knowledge to integrated knowledge and practice. It is anticipated that there remain many difficulties and challenges of integrating knowledge and action. These difficulties and challenges of action taking need to be shared among teacher and students so that we can create the community of participatory scientific literacy which is concerned of enacted and embodied knowledge and action in life contexts.

Third, to overcome the separation of scientific knowledge, there needs to provide students with scientific knowledge explicitly explained within STSE issues and employed in problem solving. Teachers can make relations between scientific content knowledge and STSE issues. For example, teaching ecosystems on one hand and discussing pollution on the other is not much helpful for students to understand the issues of pollution and the ways of problem solving in scientific contexts. STSE teaching needs to discuss directly what causes certain types of pollution in ecosystems and how they can be alleviated by scientific and technological problem solving. This means STSE teaching should not perpetuate the ways of being add-on or corner box story telling as separated from content knowledge.

To encourage participatory and responsible roles of scientific literacy, STSE education needs to reconsider ways of addressing STSE issues and embodying the issues through action. Knowing of concepts and issues is a fundamental step of participatory scientific literacy; however, passive awareness or separated knowledge from action is not a desirable way of knowing. In this regard, simply addressing STSE issues does not necessarily bring forth the praxis of scientific knowledge. STSE issues need to be taught and integrated in scientific knowledge and inquiry process so that they can be understood and enacted with collaboration of scientific and technological mediations. To promote scientific literacy enacted within life contexts, there will need more consistent and strategic efforts to bring forth STSE issues with scientific knowledge and action.

References

Aikenhead, G. (1994): What is STS science teaching? In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform*, (pp. 47-59). New York & London: Teachers College Columbia University.

Aikenhead, G. (2006). *Science education for everyday life: Evidence-based practice.* New York: Teachers College Press.

Barnett, M., Lord, C., Strauss, E., Rosca, C., Langford, H., Chavez, D. & Deni, L. (2006). Using the urban environment to Engage Youths in urban ecology field studies. *The Journal of Environmental Education, 37(2),* 3-11.

Bell, R. & Lederman, N. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Science Education, 87(3)*, 352-377.

Cox, S. (2005). Intention and meaning in young children's drawing. *Journal of Art & Design Education, 24(2)*, 115-125.

Colucci-Gray, L., Camino, E., Barbiero, G. & Gray, D. (2006). From scientific literacy to sustainability literacy: An ecological framework for education. *Science Education, 90(2)*, 227-252.

DeBoer, G. (2000). Scientific literacy: another look at its historical and contemporary meanings and its relationship to science education reform. *Science Education, 37(6)*, 582-601.

Driver, R., Leach, J., Millar, R. & Scott, P. (1996). *Young people's images of science.* Buckingham & Philadelphia: Open University Press.

Fisman, L. (2005). The effects of local learning on environmental awareness in children: An empirical investigation. *The Journal of Environmental Education, 36(3), 39-49.*

Galbraith, P., Carss, M., Grice, R., Endean, L. & Warry, M. (1997). Toward scientific literacy for the third millennium: a view from Australia. *International Journal of Science Education, 19(4)*, 447-467.

Gallagher, S. (1997). Hermeneutical approaches to educational research. In H. Danner (Ed.), *Hermeneutics and Educational Discourse* (pp. 129-148). Johannesburg: Heinemann.

Geelan, D. (2004). *Weaving narrative nets to capture classrooms: Multimethod qualitative approaches for educational research.* Dordrecht, Boston & London: Kluwer Academic Publisher.

Hodson, D. (2003). Time for action: science education for an alternative future. *International Journal of Science Education, 25(6),* 645-670.

Hurd, P. (1998). Scientific literacy: New minds for a changing world. *Science Education, 82(3)*, 407-416.

Hurd, P. (2002). Modernizing science education. *Journal of Research in Science Teaching. 39(1)*, 3-9.

Jenkins, E. (2000). 'Science for all': times for a paradigm shift? In R. Miller (Ed.), *Improving science Education: the Contribution of Research* (pp. 207-226). Buckingham, UK: Open University Press.

Kollmuss, A. & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Re-*

search, 8(3), 239-260.

Kolstø, S (2000). Consensus projects: teaching science for citizenship. *International Journal of Science Education, 22 (6)*, 654-664.

Kolstø, S. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education, 85(3)*, 291-310.

Kozoll, R. & Osborne, M. (2004). Finding meaning in science; Lifeworld, identity, and self. *Science Education, 88(2)*, 157-181.

Kress, G. & van Leeuwen, T. (1996). *Reading images: The grammar of visual design*. London & New York: Routledge.

Lincoln, Y. & Guba, E. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage Publications.

Mander, J. (1996). Technologies of globalization. In J. Mander & E. Goldsmith (Eds.), *The case against the global economy* (pp. 345-359). San Francisco: Sierra Club Books.

Matthews, J. (2003). *Drawing and painting: Children and visual presentation*. London, Thousand Oaks, & New Delhi: Paul Chapman Publishing.

Pedretti, E. (2003). Teaching science, technology, society and environment (STSE) education. In D. Zeidler (Ed.), *The role of moral reasoning on socioscientific issues and discourse in science education* (pp. 219-240). Dordrecht, Boston, & London: Kluwer Academic Publishers.

Ring, K. (2001). Young children's drawing: The significance of the context. *Paper presented at the British educational research association annual conference*, University of Leeds, 13-15 September 2001. Available at www.leeds.ac.uk/educol/documents/00001927.htm

Roberts, D. (1995). Building companion meanings into school science programs. *Nordisk Pedagogik, 15(2)*, 108-124.

Roth, W.-M. & Desautels, J. (2004). Educating for citizenship: Reappraising the role of science education. *Canadian Journal of science, mathematics and technology education, 4(2)*, 149-168.

Shepardson, D. (2005). Student ideas: What is an environment. *The Journal of Environmental Education*, 36*(4)*, 49-58.

The Council of Ministers of Education (1993). *Common framework of science learning outcomes, K to 12*. Canada: The Council of Ministers of Education.

Willinsky, J. (1998*). Learning to divide the world: Education at Empire's end*. Minneapolis: University of Minnesota Press.

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.

Zeidler, D., Sadler, T., Simmons, M. & Howes E. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education, 89(3)*, 357-377.

Ziman, J. (2000). *Real science: What it is, and what it means*. Cambridge, MA: Cambridge University Press.