

Rethinking the Ethics of Scientific Knowledge: A Case Study of Teaching the Environment in Science Classrooms

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In this paper we argue that scientific literacy ought to be rethought in that it involves ethics as its core element. Considering the fact that science education has addressed ethical dilemmas of Science, Technology, Society and Environment (STSE) issues, it is worthwhile to question what the ethics of scientific knowledge mean in terms of their implications in modern society where knowledge generally is separated from action and thereby from the responsibility for knowing. We draw on the concept of integrity of knowing to analyze knowledge about the environment in Korean sixth-grade science classrooms. Examining the notion of immediate coping and Confucian *Cheng*, we differentiate 'knowing about ethics' and 'knowing ethically' with respect to STSE issues. We challenge the notion of knowing, suggesting instead that there is not only knowing *about* but knowing *in* and *for* action. Participatory scientific literacy ought to aim for the latter form of knowing. This understanding of ethics and scientific literacy could help science educators bring forth the responsibility for knowledge in science classrooms by encouraging students to become active and responsible concerning STSE issues.

Keywords: ethics of knowledge, integrity, Science-Technology-Society-the Environment education

History of the Issue

Historically, science education has meant learning sets of concepts that laboratory scientists thought to be foundational to their disciplines. Thus, a brief look at science textbooks shows that science education generally asks students to memorize such things as Newton's Law of

Gravity, the Krebs cycle, or the process of oxidization/combustion. When science educators came to realize that knowing a concept means knowing it in relevant contexts, they began to consider including the discussion of STSE issues in the classroom such as missile launches and the social aspects of the relationship between combustion and the atmosphere (Aikenhead, 1994). It is up to students themselves to choose what they want to do with the conceptual knowledge, for example learning Krebs cycle for school tests. However, this does not coincide with the purposes of Science, Technology Society, and the Environment (STSE) education. The underlying idea is that discussing STSE issues provides students with a means of linking what they learn in science classrooms and their everyday world outside (DeBoer, 2000). This thereby constitutes a link between knowing science and responsible

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citizenship, which in turn leads science educators to suggest that science students of all ages ought to get involved in changing their worlds (Roth & Désautels, 2004). Increasingly science educators become concerned with the gap between knowing science and acting in ways that embody this knowledge.

From an ethico-moral standpoint, the desirable form of knowing is 'knowing in and for action'; preparing students for action means ensuring that they gain an understanding of how decisions are made within a variety of everyday contexts (Hodson, 2003). In the concept of *phronesis*, that of wise practical action, the ancient Greeks already knew that decision-making inherently involved ethics. As a way of cultivating scientific literacy for citizenship, the STSE curriculum development addresses ethical dilemmas of socio-scientific issues to help students make informed decisions and take action in a complex modern society (Sadler & Zeidler, 2004). Given that scientific knowledge and collective decision-making could have a great impact on health and the environment, it becomes necessary for students as future citizens to understand the complexity of STSE and human ethical relationships in their everyday life. Some science educators design learning environments in which students argue about real STSE issues in the confines of their classrooms (Kolstoe, 2000); others see such an approach as artificial and suggest instead involving students directly in a real everyday activity outside of schools so that their knowing and learning might have immediate consequences for their community (Roth & Lee, 2004). It is in and through their practical work relative to environmental issues that students act ethico-morally and develop ethico-moral actions (Roth, 2008).

Despite the concerns and efforts to support students' development of scientific knowledge in relation to civic responsibilities, STSE education has been taken as an add-on or peripheral under the scheme of content-oriented science curricula and has not made much progress in terms of the connection of scientific knowledge, decision-making, and taking action in real life (Kolstoe, 2001; Robert, 1995). Most science curricula in schools today still focus on factual knowledge in that they mostly involve the laws, theories, and concepts of science without responding to the rapid changes in the practice of science and technology, the information age, and human life values (Hurd, 2002). Even while teaching STSE, many and perhaps most science

teachers address ethical dilemmas without much consideration of students' personal emotional understandings of the issues as if the issues are the problems or the situations of others (Zeidler et al., 2005).

To discuss the importance of rethinking ethics in STSE education, we propose thinking about the following case study in a sixth-grade Korean classroom. It exhibits the complexity of knowledge and action, allowing us to examine what the praxis of knowing means from an ethical perspective. We argue for knowledge as enactive and embodied in action. We draw on Confucian ideas about *integrity* and *harmony* of knowing to discuss the ethics in and of scientific knowledge. In the Confucian approach to knowledge and knowing, knowing and acting are inseparable. This notion of knowing leads us to contemplate the ethics and harmony of knowledge, which contemporary science and technology has yet to take into consideration.

An Overview of the Case Study

In Korea, science educators and researchers have attempted to include STSE in the science curriculum for about two decades. However, in practice, this has meant focusing on scientific concepts and skills. This notion is not surprising in a society where education is oriented toward students' achievement and competition. This tendency constrains teachers from a meaningful approach to STSE that deals with values, ethics, and responsibilities of knowing. Even if teachers focus on STSE issues, they tend to focus on empirical, neutral, and value-free knowing.

The purpose of this case study is to search for the meaning of STSE knowledge by studying early forms of public understanding of science existing in the form of children's knowledge of the environment as it is taken into consideration in public Korean elementary science classrooms. Concerning the ethical aspects in STSE knowing and teaching, our case study concerns science classrooms where children are learning about ecosystems and the environment. The unit was taught for 6 weeks by the first author. To understand children's knowledge and attitudes toward the environment, a research instrument, CHEAKS (Children's Environmental Attitudes and Knowledge Scale) has been introduced in environmental education studies (Leeming & Dwyer, 1995). This

instrument, consisting of two sub-scales; Attitudes and Knowledge and the CHEAKS Total Scale, is a valuable method to understand the relationships between children's knowledge and attitudes to environmental issues. There is also another method, the ROSE (the Relevance of Science Education) questionnaire, introduced by a science education group. It aims to examine children's understanding of complex relationships between science, technology, and the environment (Schreiner & Sjøberg, 2004). The ROSE includes the interests, everyday experiences, and opinions about science, technology, and the environment of children. Both instruments are valid and useful to investigate children's understandings of and actions in relation to environmental issues. With respect to our concerns with the issues of STSE knowledge with an emphasis on the environment, we adapted the ROSE instrument in this study.

At the beginning of the study, we conducted a survey questionnaire derived from the ROSE questionnaire. This questionnaire was developed for an international project to study young people's understandings of the relationships between science, technology, society and the environment in science education. In the ROSE questionnaire, we particularly focused on "Part D: Environmental challenges and Me" and "Part G: My opinions about science and technology." We selected those 30 of the 34 items in the two parts that are relevant to the relationship of science, technology, and the environment. We added 3 items to enquire about the relationships between science learning and environmental issues. More than 130 sixth graders (ages 11–12) were invited to complete this survey, which provided us with an overview of the participating school children's understandings of science, technology, and environmental issues.

To be able to reflect upon children's understandings more thoroughly and interpretively, we collected children's narratives on their experiences of everyday environments. We invited 45 children (23 boys and 22 girls) in one classroom to participate in open-ended group interviews and to produce reflective writing throughout an STSE unit. This class was selected as a convenient sampling. The children participated in groups of 3–4 and each interview lasted between 30 to 40 minutes. The interviews were semi-structured with open-ended questions. The reflective writing activities took place during science lessons where the researcher collected them. Informal discussions among

children were also noted and entered into the database. Interviews and classroom discussions were audio- or videotaped and transcribed in their entirety for analysis. The researchers followed the precepts of grounded theory (Corbin & Strauss, 1990), initially coding and categorizing the data sources and discussing them with others in our research laboratory for the purpose of submitting emergent categories to review by peers not involved in the study. The themes and arguments of the study were saturated and developed coherently over the discussions.

The Findings

Being Aware of Issues

In children's understandings of ecosystems and the environment, there were two main dimensions: *nature*, thought to be distant from their everyday lives, and the *city environment*, in which they live. In this divided understanding, 79% of the children answered that the city in which they live is not a living ecosystem whereas the natural environment helps them to live healthy lives. The contradictory relationship between natural places and city environments was clearly noticeable. The majority of the children agreed that they experienced environmental pollution and were aware of environmental problems. We present some results of the questionnaires that are modified from the ROSE as follows.

The results of the questionnaire may not be surprising in a place where the population density is high—in Seoul there are about 11 million people living on 605.52 square kilometers, a population density of 18,000 people per square kilometer. In such a context, environmental issues have become social concerns. As constitutive members of society, children are exposed daily to public conversations and concerns about environmental problems through the mass media, journals, books, and education in their everyday lives. Under these circumstances, it is likely that children come to hear about issues concerning the environment.

This awareness is evident in children's narratives. Many children's stories contain narratives of environmental destruction. Some of the images are striking:

I was on the way home. I started coughing hard. A car honked really loud on the road and made my ears

Table 1
Children's Understandings of Environmental Issues

Items	strongly disagree %	disagree %	agree %	strongly agree %
Environmental problems are not my concern.	62	26	8	5
Environmental problems concern me.	5	5	31	58
Science and technology can solve environmental problems.	8	33	42	17
My personal life and behaviors impact the environment.	9	23	37	32
People are worried about environmental issues too much.	38	36	11	15
More effort in terms of environmental protection and conservation is needed.	4	8	25	63
Each individual is an important action taker for the environment.	6	19	32	42
We share the environment with animals.	18	17	42	24
The city I live in is a living ecosystem.	25	37	22	15
The environment I live in makes me healthy.	26	43	19	13
The natural environment makes me healthy.	8	22	33	38
I experience environmental pollution.	7	18	35	41

dizzy and numb. I got so scared of breathing the air from the car. I had never realized about air pollution that seriously before. (Jeon, boy, age 11)

I saw a dead frog floating on the water. There was also garbage, pop cans, plastic bags, and so many other things. I felt appalled and disgusted. Why did people do such things? (Heeju, girl, age 12)

I was visiting my grandma's place in the countryside. I saw a huge construction site to make a tunnel in the mountains near the highway. I realized when we we try to make life more convenient for ourselves, nature suffers. (Junsu, boy, age 12)

I smelled terrible sewage. 'Where is it coming from?' . . . Something was rotten. Garbage was decaying on the corner of the street. Wherever you go, you see garbage, even in the mountains and small rural towns. That's too bad. (Yoon, girl, age 12)

Many other children presented similar stories. These therefore, are typical of public understanding of STSE

issues around the age of 11–12, and they are typical of the concerns, sympathy, and reflections on environmental issues that children of this age exhibit.

Passive Awareness and Disembodied Knowing

Concerning the role of children's lived experiences and awareness mediated the attitudes they expressed, we would assume that children would be encouraged to exhibit proactive behavior with respect to environmental issues. Despite their awareness and knowledge of ecosystems and environmental issues, however, children's actions and behaviors are not necessarily accordant with their concerns or awareness. The majority of children (83%, n= 112 out of 135) answered that they did not pay much attention to doing something good for the environment whereas more than 85% of children answered that environmental problems are their concern and there need to be more and greater efforts made in taking care of the environment. Our analysis of the interviews reveals eight discursive repertoires children used to justify and explain why they were not acting in an environmentally friendly manner in their reflective writings.

Children said they still use a lot of disposable items

Table 2
Children's Reasons of Why Not Acting (N=45)

Children's Reasons	n	%
selfishness (Others can do good things, not me.)	10	22.2
laziness (I am too lazy to take action.)	7	15.6
bad habits (It is hard to get rid of old bad habits.)	7	15.6
inevitable use of everyday products (We can't live without using everyday products.)	7	15.6
difficult access to nature (Nature is too far away for me to protect.)	4	8.9
insufficient social/community programs (There are no actions or support systems from neighbors or local offices.)	4	8.9
young and tender age (I am only a child so things are beyond my limit.)	3	6.7
frustration and distrust of others' behaviors (There was no change for the better despite my efforts. I felt hopeless.)	2	4.4
I do not know. (I don't know why.)	1	2.2

such as paper, plastic, or Styrofoam cups in their everyday lives even though they knew it would harm animals, plants, land, and the whole ecosystems in the long run. To understand the gap between their awareness and everyday action, we asked them to reflect and write the reasons why they do not try to change or develop 'good' behaviors for/in the environment and their experiences when they do things that they believe are not right for the environment. The children articulated a variety of reasons why they could not act upon their awareness and beliefs; and they felt sympathetic and regretful, emotions that are usually linked to morals and ethics.

Now I am only a child so there is little I can do . . . when I grow up, I can do more to protect the environment. (Kyung, girl, age 11)

But there are some things that I can't do. Things like gas from cars or waste from factories should be taken care of by car users or factory owners. (Seon, boy, age 11)

We think that our onetime bad behavior won't harm the environment that much. Or we think it would be okay that it is only me doing this, not other people. We hope somebody else will do the right things for the environment, not me. (Heeju, girl, age 12)

Then I think about the importance of our environment . . . but my body and mind are always

doing different things. (Yoon, girl, age 12)

These excerpts show that children expressed self knowledge of their youth, the inevitabilities of an industrial society, or bad habits as reasons for not taking action. Children have developed an attitude of 'spectatorship' toward environmental problems regardless of their first-hand experiences and awareness. Some children 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 children themselves. Some parts are too far away, too abstract and immense for them to take on at an individual level. By making the separation between two different worlds; children/adults and everyday environment/nature, children do not feel responsible for some of the problems. Those problems seen outside of the children's worlds are expected to be dealt with by some other people at some other time. Fruitless efforts and lack of community collaboration make them feel disappointment toward others and uninterested in making another attempt at change. In other words, despite their small-scale efforts, they thought that environmental problems did not improve and even got worse. We understand these stories as instances in which children use a variety of discursive repertoires to account for what they do and think. These repertoires are socio-cultural, that is, they are shared not only among children but by the members of society broadly.

As illustrated clearly in Heeju and Yoon's stories, awareness or consciousness of environmental issues does

not necessarily bring forth effort, actions or behavioral changes on the part of the children. Many aspects mediate their awareness—uncertain views, emotions, bodily habits, and situational interference in the moment of action taking. Their awareness (*knowing about* ethical deeds) and their action (*enacting* ethical deeds) are not necessarily coordinated. We consider this knowing as passive and inert, which needs to be questioned in the ethical responsibility of knowing. Expressing these reasons, the children justified their lack of effort in taking good actions. Their conceptual knowing about environmental issues was not followed by their actions.

Several researchers in environmental education have discussed the complex relations among knowledge, attitude, and action (e.g., Jensen, 2002). Knowledge, attitude, and action are neither linear nor in a cause-effect relationship. In other words, knowledge does not necessarily enhance attitudes and actions. Furthermore, there is no significance in terms of children's knowledge development whereas their attitudes toward the environment were very developed through a certain environmental program (Leeming & Porter, 1997). In fact, environmental knowledge alone is not sufficient to bring about pro-environmental behavioral changes for there are internal and external aspects, especially old habit patterns that influence person's actions (Kollmuss & Agyeman, 2002). Other studies emphasize the importance of inner influences of lived experiences to enhance behavioral changes and overcome the notion of reverting back to old habits (Mainteny, 2002). Researchers also discussed the complex relationships between knowledge and practice. They indicated that there is no strong evidence that scientific knowledge is the main source of decision-making and action in science-related everyday circumstances (e.g., Bell & Lederman, 2003). Rather than scientific knowledge, sociopolitical issues, ethical considerations, personal values, and emotive dimensions such as feelings and intuitions dominate decision-making and action toward STSE issues (Dillon, 2002).

The complexity of knowledge and action has been an on-going concern in terms of empowering students to take action on STSE issues. This urges us to question what it means to teach children the knowledge of STSE and how to rethink an STSE approach to bring forth knowledge in action. These questions are meaningful in contemporary science education since the roles of science and technology

become significantly compound in social and environmental issues. In this study and other studies (e.g., Schreiner & Sjøberg, 2005), children's understandings of the relationships between science and technology turn out to be complex in terms of socioeconomic and environmental values. Under these circumstances, science education needs to address the importance of the practice of scientific knowledge in real life situations. If science and technology can bring forth possible solutions to real life problems, knowledge should take into consideration its action in individual and social dimensions, which in turn, should be sustainable and ethical.

To consider these questions, we examine the dualistic understandings of knowledge. This gap fundamentally emerges when knowledge is regarded as conceptual and action as practical or body-oriented. When knowledge /knowing is enactive, it is both conceptual and practical, that is, knowledge exists through our bodily action. In this regard, we can raise critical questions in terms of the meaning of ethics in teaching STSE issues in science education. It is how we look at children's passive awareness and disembodied knowing in terms of participatory scientific literacy for citizenship in STSE education. In fact, a wise person exhibits *phronesis*, which is ethical knowledge in action, which can be interpreted to mean that *knowing about* without *enacting* is equivalent to not knowing at all. When students' knowing about is unrelated to their decision-making and action, their concepts remain separated from responsible proactive participation as citizens. This gap raises ethical concerns in terms of scientific literacy where science and technology rapidly and complexly changes human relationships to the world. The participatory roles of scientific literacy have become vital aspects in sustainable future making. With these questions in mind, we open up our discussion on a rethinking of scientific literacy to involve 'ethics' as the core element of STSE education for contemporary science education.

Rethinking STSE Teaching to Include Ethics

As science educators' conception of scientific literacy and STSE education aims to help students understand the links between knowledge and responsible decision making and action, it becomes necessary to challenge separated

views of knowledge and action in STSE contexts. To challenge the gap that frequently exists between scientific knowledge (i.e., *knowledge about*) and practical action from ethical perspectives of participatory scientific literacy, we introduce in this section the idea that everyday practical action (praxis) *embodies* knowledgeability, which is a form of knowing that also includes ethical practice. To discuss embodied knowledge and action, we draw on Confucius, who provides us with the sought-for concept in the following.

Cheng: The Integrity of Knowing and Doing

English, as other Western languages, does not have a concept in which the intention to act (as available in a word) and ethics are combined. Such a combined concept does exist, however, in the Confucian concept *Cheng* (誠), which embraces ethical knowledge in our being and living. As one of the main rules to be an exemplary person, one needs to know how to be quick in practice with wisdom and respect to others (Ni, 2002), which is the basis of immediate coping of ethical expertise (Varela, 1999). *Cheng* has been introduced in the western world as sincerity, truthfulness, integrity, or faithfulness. Meaning ‘being true to oneself’, *Cheng* emphasizes “an inner-oriented action to unify the person as intentional agent with his original, natural self” (An, 2004, p. 156). To be sincere and truthful to one self is to conduct actions in the goodness of one’s knowledge and the reliability of one’s words. To understand the truthfulness of knowledge and action, we attempt to analyze the structure of the word, *Cheng* (Figure 1).



Figure 1. The character *Cheng* consists of two parts meaning ‘word’ and ‘completion’, respectively. Together they denote ‘integrity’.

Cheng consists of two parts: The left part (言) means

word and the right part (成) means completion; as a whole, this character denotes ‘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. One tries to be true to one self by completing what one knows one’s knowledge and word in one’s action. Living with the notion of *Cheng* is 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. One’s knowing (言, word) seeks an ethical stance through one’s action (成, completion). To be such a ‘person,’ knowing should be completed in doing. This integrity of knowing and doing constitutes ethical knowledge, which pertains not only to being true to one self but also to one’s relationships with all other members of society (Huang, 2001). This expands ethics in individual action to collective action.

As *Cheng* embodies ethical values in one’s knowing: One is not free from the responsibility and ethics of action when one understands the importance of word completion. That is, it is always co-committed with one’s value judgment and emotional engagement. When the integrity of knowing lacks in one’s action, one is not truthful or ethical to oneself and to the situation. It embodies some degree of guilt, discomfort, regret, and shame. Children’s narratives that we collected during the unit show the evidences of these feelings. Whatever their reasons would be, children experienced discomfort and inner conflicts when they experienced the disintegration between their knowing and action regarding the environmental issues. On the contrary, they experienced fulfillment, contentment, and self-esteem when they completed their actions according to what they thought was right. In children’s efforts to practice morally good deeds, the authenticity of action emerges and encourages them to continuously strive for good actions.

I felt a bit ashamed when I did that (littering)...
(Jeong, girl, age 12).

I throw garbage away quickly again. . . Then I kept thinking that I should pick the garbage up. I could hear ‘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 dropped when nobody was watching me. I sometimes think I wish I

could throw this shameful feeling away with the garbage too. (Min, boy, age 11)

I decided to finish food even though I don't like to but it's not easy. However, 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 bad habits', suddenly that thought came into my mind. Now I am trying to use less water. I don't run the 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. . . . I am eager to share my ideas with people so that we could live more frugally. (Dojin, boy, age 12)

Jeong felt ashamed when she did something that she thought was not right. When Min was thinking that he should pick up the garbage and his body did not do so, he felt guilty not being proud of himself while Dojin felt contentment and confidence in his integrated action. There are emotional engagements that encourage or discourage one's ethical action. In fact, when there is damage to the frontal lobes of the brain, which regulates emotions, a person may continue to reason appropriately about ethical issues, yet act in morally reprehensible ways (Damasio, 1999). This notion of integrity and truthfulness can be vital to rethink the ethics of one's knowing and action. It also brings forth the importance of active participation of scientific literacy to fulfill one's becoming a person, the ethical expert in the discourse of STSE issues. How then, do we cultivate ethical expertise with integrity in one's lives?

Knowledgeability; Knowing as Praxis

Human actions exhibit knowledge, even though the acting person frequently does not or cannot articulate this knowledge in verbal form. Good football players or cooks exhibit their knowledge in how well they play and how well they cook rather than in using physical or chemical discourse to talk about what they do. Their knowing lies in their capacity to knowledgeably act in the multitude of situations characteristic of their professional lives. That is, knowledge is embodied in our knowledgeable coping with everyday situations (Heidegger, 1996; Varela, 1999). Here,

knowledgeably coping is to be understood as the way in which we act in familiar everyday situations (Dreyfus, 1991), where we do not have to reflect and deliberate about what to do next: We walk rather than place feet and we eat rather than calculate the trajectory of a spoon from the bowl to our mouth and then implement the movement with our hands. Knowledgeability and knowledgeable coping constitute knowing as praxis; they are characterized therefore by knowing in action rather than by knowing about something.

Varela (1999) introduced the notion of immediate coping and ethical expertise in his work, *Ethical Know-How*. We already know how to do things in everyday situations on the basis of recurrent observations made during participation in the multitude of situations that we face each day such as using a spoon to eat soup from recurrent actions. When we repeat actions to cope with a certain situation, we become experts in that situation. Who we are, therefore, in a very pervasive way, arises from our participation in the multitude of micro-events that together constitute our lives. During everyday life, we are also confronted with contradictions or breakdowns of situations which challenge our decision making and behavioral patterns. Breakdown and contradictions emerge when our normal, embodied, and tacit ways of knowing no longer work for one or another reason. In such cases, it is possible to question which stance is going to best respond to the very situation of contradiction or breakdown. Here is where our ethical stance comes into play. We try to cope with a situation at hand, even a novel situation, with ethical appropriateness and immediacy. This is where we are challenged with responsible decision making and with taking action in immediate situations.

Immediate coping in contradictions and breakdowns is not a simple or reflexive action but a process that needs considerable time and praxis to develop. It is a process of embodying our knowing and learning over time. This act of immediate coping takes much wisdom and authenticity to allow us to evaluate the situation with moral judgment and understand the consequences of action in no time. It exemplifies highly skillful and mindful decision making and action in terms of the situation and context. Ethical expertise with intelligent awareness and wisdom knows how to respond appropriately and immediately to a situation at hand.

The Harmony of an Enminded Body and Embodied Mind

Intelligent awareness in the moment of immediate coping always takes a middle way to guide our actions in harmony with the texture of the situation (Masciotra, Roth, & Morel, 2007). To understand the relationship of integrity (*Cheng*) and harmony in immediate coping and as a way of doing/living ethically and wisely, it is valuable to draw upon two other key Confucian concepts: *Li* (禮) and *Yi* (義). These two concepts are joined in the concept of middle way/harmony, person making/ becoming an 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 supports innovation and the creativity of cultural traditions. *Yi* means righteousness or the appropriateness of actions; *Yi* is intrinsically intertwined with the particulars of a setting. *Yi* is a standard relating to decision-making or conduct; therefore, it is fundamental to the dynamics of persons acting with integrity (Hall & Ames, 1987; Lee, 2001).

In Confucian epistemology, learning through ritual actions is important to personal development. To manifest the relationships between *Li* and *Yi*, here is the simple example of how a child learns the concept of respect. 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 the Korean tradition, these are the ways of exhibiting respect for an older person. Children do not know what it means at the time they learn the concept; but they learn to act in certain ways from their parents and elderly people. By repeating the action, one slowly learns the concept of respect and comes to know the appropriate situations in which to 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 bows 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*. Bowing becomes a ritual of respect and the child embodies the meaning in his/her action.

To understand this concept in a Western context, we

can think about the example of queuing in a public place. Children learn to queue (*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. This learning through bodily action reinforces the integrity of knowing and immediate coping for the body already knows and does what needs to be done. There is no way to distinguish outer actions from inner meaning or vice versa when *Li* and *Yi* are combined and practiced in harmony. For example, in Dojin’s action of shutting off the water (*Li*), his concern about the environment (*Yi*) is intermingled. As contrary examples, we consider the stories of Yoon. Yoon explained she could not complete her thinking in her action because her bodily habits were already orienting her action in different ways. In her earlier story, she understood the garbage problem and wanted to do something good but her action consisted of throwing the garbage away. The disharmony and contradictions of those actions are our pedagogical challenges in the ethics of STSE knowledge.

Actions with regard to integrity of immediate coping 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. “The state is one which they not only *know* what is expressive of humanity but also *become* authentic humans” (Ni, 2002, p. 64). Harmony or the middle way is about one’s self but also about the relationships between time and space. It is when we reach harmony and the middle way that the moment of knowing is achieved. An exemplary person in Confucian theory and a person who possesses ethical expertise refer us to the same kind of human being—someone who has the wisdom of harmony and integrity and always conducts himself or herself appropriately. This person immediately acts in a situation—without having to decide which to take on among the theoretical, technical, or ethical knowledge—because their wisdom of knowing is already embodied in their actions.

From this perspective, continually practicing virtues and good behavior is one of the fundamental ways to conduct ethical actions in immediate coping. Similar 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 leads 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. We strive to train ourselves in good habits of mind and body through reflecting on what we know and what we do, and letting our desire go in order to fulfill the mindfulness of action (Bubryun, 1994). This mindful questioning and thinking of knowledge and action is the ethical component of knowledge and needs to be developed in the complexity of STSE education.

Discussion

Scientific knowledge has long been free from values and ethics. Even in STSE education, which is concerned with ethical issues of science and technology, the gap between knowledge and action has not been discussed significantly since it has adopted the linear model of knowledge and action. However, the ethical domain of STSE knowledge is not only found in awareness but in action. An important difficulty for teaching ethics of scientific knowledge comes from the epistemology inherent in science and science teaching: Splitting mind from the body, humans from nature, and subjects of knowing from their objects of knowledge understanding, scientific knowledge is freed from human subjectivity and values in the everyday world. In addition to the splits between mind and body and between subjective and objective knowing, a binary assumption of science and knowledge leads to a split between having particular scientific knowledge and the ethical implications of human actions taken as a result of that knowledge (Elmose & Roth, 2005). In this respect, we rethink of children’s knowing that is disconnected from

responsible actions by their own defensible reasons (young and tender age, bodily habits, actions beyond their age or ability, peer pressure, lack of collaboration, etc.). In the conceptual domain of knowledge, students’ acquisition of ethical dimensions of STSE issues do not necessarily concern bodily practice and actions of their knowledge to claim ‘to know’ the ethics in content- and text-oriented science learning. The 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; ethics has been abstracted from practical action of which the former is an inherent feature and without which it does not represent real human praxis (Bakhtin, 1993). Such an approach, in which ethics is abstracted from theoretical knowledge, seemingly exempts us from the responsible actions that would otherwise follow from knowledge. It often leads us to ignore immature and irresponsible applications of knowledge in modern scientific and technological enterprises. This separate knowing about ethical dilemmas of socio-scientific issues needs a thorough examination in terms of ethical relationships of our knowledge to the society.

To cultivate the ethics of STSE knowing in terms of integrity and phronesis, we address three pedagogical aspects in STSE education. First, there needs to be an emphasis on integrity (*Cheng, phronesis*) as a true form of STSE knowledge in modern science and technology education which should no longer be separated from human values and ethics. From the perspectives of integrity of STSE knowing, we revisit the children’s narratives. When children placed the problems and responsibilities beyond their lifeworlds, the issues became abstract and distant and hence, further actions were difficult. Nevertheless, despite their tender age, some children already made use of discursive repertoires that divested them of the responsibilities for acting ethically. Their understandings turned into spectatorship or even self-justification. This disconnection of students’ personal, disembodied, and moral understandings of STSE issues deprives functional and practical aspects of science as it pertains to the everyday world and life. In this circumstance, students’ awareness and understandings of STSE issues remains in the conceptual domain of knowledge being separated from their decision making and action in everyday life situations, which challenges students’ scientific literacy to participate

in and act on the complex relationships of STSE issues. This separated knowledge from action must be recognized and examined through mutual dialogues in STSE classrooms.

Second, science teachers need to provide students with opportunities to reflect on their own experiences of the gap between knowing and acting. This possibly brings about emotional engagement such as disturbance, contentment and empowerment. As seen in our children's narratives, there are value-laden feelings such as guilt, remorse, and shame at work when their actions were detached from what they thought was right. When action took place according to what was right, children experienced more positive feelings. There was much potential to encourage students to get engaged in mindful reflection and discussion on the integrity of knowledge (the harmony of *Li* and *Yi*). Such development and discipline toward integrity is a way of transforming passive awareness into solid and participatory grounds for knowledge. This process requires consistent and collective efforts, which challenge us to cultivate an understanding of scientific literacy as embodied knowledge. The gap between conceptual knowledge and practical action is to be challenged in the vision of scientific literacy for participatory citizenship to bring forth ethical and sustainable relationships of being and living in this world. This process needs to be emphasized in science classrooms.

Third, as suggested in the concepts of *Li* and *Yi*, recurrent practice is one of the key aspects to embody knowing in action. This process takes time and patience, hence, needs to start at young age so that the ethics of STSE knowing can be embodied in the construction and internalization of knowledge *in* and *through* action. As the way to harmonize *Li* and *Yi* suggests, recurrent practice leads us to ethical expertise in everyday coping. This also means that STSE teaching needs to be grounded in everyday life contexts so that students can act on them. When issues are remote from their own lifeworlds or the range of action taking is out of their reach, decision making process and suggested action become vague and unrealistic. STSE education needs to empower STSE relationships within and through our own bodies and lives and look for possibilities to expand its boundary toward others, citizenship and world contexts.

Coda

In making, holding, evaluating, and using knowledge, our actions are already disposed toward responsibility: "the possession of knowledge carries with its moral obligation" (Mayor, 1999, p.166). The ethical relationship between knowledge and action needs to be recognized in a more modern and responsive view of scientific literacy. The concepts of *Li* and *Yi* provide us with resources to rethink and practice STSE education that is applied and makes ours a better world. Without such integration, we cannot claim that we truly know or understand what we think we know. In modern society, science is valued as scientific knowledge and wisdom and ethics of knowing tend to be disregarded in scientific knowing. Without contemplation of the integrity of knowing and doing, science education has been seeking a way to create scientific literacy for citizenship. When science teaching perpetuates this tendency of separated knowledge, learning about ethical dilemmas of STSE issues might also turn out to be little more than knowing *about* the ethical components of the issues. This way of knowing ethics does not necessarily bring forth the ethical responsibilities which make for decision making and citizenry action. As our case study showed, children's knowing about environmental issues comes to be distant, disembodied, and disempowered. This taken-for-granted disintegration of knowledge needs to be questioned, examined, and overcome to cultivate responsible and participatory dimension of knowledge as the ethics of scientific knowledge. In our pedagogical responsibility, we attempt to change children's passivity toward environmental problems into empowerment with the fulfillment of integrity in knowing and action. We are to encourage students with confidence of integrity in their own actions. In this way, we help them become responsible and active citizens in the discourse of science and technology in the modern era. Understanding the integrity of knowing as ethics ensures that our conception of scientific literacy requires interactive and proactive participation in our everyday living as implicit and explicit consequences of knowing. Understanding knowledge as embodied and integrated action, STSE education explores ethics not only in the conceptual domains of STSE issues but also its praxis in life worlds. That is, the ethics of STSE knowledge is not only knowing *about* ethical issues but also ethically knowing

and living *with-in* the issues.

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