# 물에 관한 고등학생들의 환경 과학적 소양과 태도

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# High School Students' Environmental Science Literacy for Water and Attitudes toward Environment

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## 논문요약

이 연구의 목적은 고등학생들의 물 문제와 관련한 환경과학적 소양과 태도를 이해하기 위한 것이다. 2010년 1학기 동안 서울시 소재 공립 국제고등학교 남 · 녀 학생 123명을 대상으로 물에 관한 환경과학적 소양과 태도에 관하여 연구하였다. '물에 관한 환경과학적 소양검사' (ESLW)와 '개정 친환경적 태도검사' (Revised NEP scale)를 사용하였으며, 검사 결과는 기술분석과 내용분석을 하였다. 연구대상 고등학생들은 물 자원 보존의 필요성을 인식시키는 것이 중요하다고 하였으나, 자신들의 실제적인 물 사용 태도와는 거리가 있었다. 또한, 이들은 물의 상태변화에서 비가시적인 현상이나 수계 사이의 물질변환에 대한 과학적 이해에 어려움을 겪었으나, 상당한 수준의 친환경적인 태도를 나타내었다. 이러한 결과에 기초하여 연구자들은 물 환경과 관련한 과학적 이해, 물 문제에 관한 환경과학적 지식과 실제적인 경험 및 친환경적 태도간의 차이를 좁힐 필요가 있다는 점을 발견하였으며, 이는 물 부족문제와 수질환경, 그리고 수자원 보존과 관리에 관한 과학적 이해를 위한 좀 더 통합적이고 간학문적인 과학교육과정의 필요성을 시사한다.

*주제어: 환경과학적 소양, 환경에 대한 태도*

## ABSTRACT

The present study aimed to understand high school students' environmental literacy for water and their attitudes toward environment. This study was conducted during the spring of the 2010 academic year with the participation of 123 students from a public international high school located in Seoul. The Environmental Science Literacy for Water test and the Revised New Ecological Paradigm scale were administered, and the data were analyzed by descriptive statistics and content analysis. The high school students in this study put strong emphasis on encouraging others to conserve water resources. This belief, however, was not aligned with self-recognition of their own roles in water supply shortages and other problematic water-use behavior. They also had difficulties in understanding the invisible part of matter transformations in water systems. Nevertheless, they showed favorable attitudes toward environmental conservation. In conclusion, the researchers suggest recognizing our own water problems and narrowing the gap between environmental and scientific knowledge of water and actual attitudes about the environment through curricular incorporation of interdisciplinary environmental science literacy into school science.

***Key words*** : environmental science literacy, attitudes toward environment

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# I. Introduction

In contrast to the numerous studies completed in the West, there is very little research on knowledge and attitudes of students toward environmental science for water issues in Korea. Basically, the interdisciplinary attempt of teaching and learning of human-engineered and natural water systems and processes has not been an important issue in the Korean National Science Curriculum Standards (Ministry of Education, 1997; Ministry of Education and Human Resources development, 2007) until a new subject, "Environment and Green Growth" entered into the 2009 Revised National Curriculum (Ministry of Education, Science and Technology, 2009) which is not yet adopted in K-12 schools in Korea. Likewise, the attitudes toward environmental science issues in school science had not been given attention. In recent decades, however, environmental problems have evolved in significant ways. Environmental problems have generally tended to become more geographically dispersed, less directly observable, and more ambiguous in origin. Moreover, environmental issues achieved recently a prominent position in our nations' policy agenda (e.g., Presidential Committee on Green Growth, 2010). Currently, high school science textbooks do not address the water quality issues in the 10th grade "Environment" unit but incorporates it as a subsidiary topic to biological magnification under the influence of the revised 2007 school science curriculum (Ministry of Education, Science and Technology, 2007). Attitudes toward environment also has seldom been explicitly issued in school science curriculum. This, in fact, is contradictory to current trend of global interdisciplinary claims from both natural science and educational research fields (Blank & Brewer, 2003; Bybee, 2003). In actuality, the incorporation of some environmental issues into 10th grade science has not guaranteed teaching and researching attitudes toward environment unlike from scientific attitudes. This eloquently reminds us the importance of evaluating and promoting students' interdisciplinary environmental scientific attitudes in school science teaching. Attitudes toward environment, including references to the value of nature as well as the duties and obligations that human has to other parts of nature and to future generations of humans is central to modern democratic citizenship that we, educators want our students to achieve.

The present study examined firstly Korean high school students' understanding of water and water quality in the interconnectedness of human-engineered and natural water systems. Additionally, we measured students' attitudes toward environment using a Revised New Environmental Paradigm (NEP) Scale (Dunlap et al., 2000). We report a part of our study on high school students' environmental science literacy for water and attitudes toward environment. The main focus is placed on assessment of high school students' current knowledge and attitudes regarding water and water systems. We had developed an assessment test for environmental science literacy for water.

*Research Questions*

- To what extent do high school students understand water and water quality?
- What attitudes toward environment do high school students hold?

# II. Background

This paper presents research on students' thinking about water and characterizes trends in students' thinking about water, water quality, and water systems. Protecting freshwater supplies is fundamental for sustaining life and societies on Earth. An important goal of science education should be preparing our students to become environmentally literate citizens who can participate in the collective decision-making processes necessary to maintain and protect adequate fresh water quality and quantity for people and natural ecosystems. The current K-12 curriculum does not support students in building a coherent understanding of the structures and processes associated with water quality, movement and distribution of water. Students may learn about the water cycle as a single circular representation presented in elementary school, then study phase changes of water in physical science in middle school and study suspensions and solutions in high school chemistry. In order to develop a more coherent curriculum, we must understand more about student thinking and learning about the structures and processes that move water and substances through water systems.

## Environmental Science Literacy for Water

We adopted the definition of environmental science literacy from Anderson et al. (2006) and explain environmental science literacy as the capacity to understand and participate in evidence-based decision making about the effects of human actions in environmental systems. This definition aligns with Coyle's (2005) description of third-level learning, or true environmental literacy. Coyle distinguished "environmental literacy" or the third level of learning from "environmental awareness", the first level of learning, and from "environmental knowledge", the second level of learning. Coyle's true environmental literacy starts out with framed information but also involves imparting the subject's underlying principles, the skills needed to investigate the subject, and an understanding of how to apply that information. The need for an environmentally literate citizenry is evident given the scientific consensus that human populations are fundamentally altering the natural systems that sustain life on earth (Cho, 2007; Pickett et al., 1994). Today, all citizens need to be able to understand environmental issues and make informed decisions that will help maintain and protect Earth's life-supporting systems. As Cho and Anderson (2006) asserts, science need to serve as one critical tool in making informed environmental decisions.

## Attitudes toward Environment: New Ecological Paradigm

Arcury and Christianson (1993) argued that there is not a consistent variable that we know to explain and interpret the foundation of environmental attitude. The New Environmental Paradigm (NEP), however, had been the most widely used measure of attitudes toward environment ever since Dunlap and Van Liere (1978) published it and we adopted the revised NEP scale that is considered to be adequate for our study despite of the cautions against categorizing individual items as clear-cut indicators of attitudes or beliefs (Eagly & Kulesa, 1997).

The NEP defines pro-environmental orientation in a new concept reflecting contemporary environmental thought and values. Briefly, the term NEP focuses specifically on balance of nature, limits of growth, and acknowledges limits of control over natural processes. NEP emerged in opposition to the Dominant Social Paradigm (DSP) which basically mirrored the values of prosperity, economical growth, and a commitment to a free trade economy and to property rights. It is rooted in the post materialist theory devised by Inglehart (1977) who claimed that the changes in societies in 1970s tend from materialistic values such as economic and physical security to freedom, self- expression, and the quality of life or post-materialist values (Abramson & Inglehart, 1995). In modern societies, according to Belchior (2010), a substantial change is occurring in the priority of political values. That is, post-materialist values related to concerns of a cultural and social nature and issues of quality of life are taking the place of traditional materialist values of political and economic stability and physical safety.

## Environmental Science Studies on Water Literacy

Research on children's understandings about water has focused on identifying common naïve conceptions about phase change, with some work on students' ideas about water as a natural system including some hydrologic processes such as precipitation and evaporation, etc. We take this work as a starting point for our research. There are, however, some prominent gaps in research concerning students' ideas about water. Recently, Covitt et al. (2009) developed a framework of water in environmental systems and we adopted this framework of water systems and addressed our students' understanding of water in terms of fresh water supply, distribution of water, environmental problems, managing water crisis, and properties of water, and attitudes toward environment measured by the revised NEP scale.

Many researchers worked on students' understandings of processes that move and documented common ideas about evaporation, cloud formation, and rain. For example, children tend to think about clouds as bags of water or sponges with drops of water in them (Bar, 1989). Younger students may recognize that water that evaporates goes someplace else (Lofgren & Hellden, 2008), or they may explain that water changes into something else, such as smoke or cotton (Bar, 1989; Osbourne & Cosgrove, 1983; Taiwo et al., 1999). Older students may mention that heat is involved, and later may describe evaporation as involving molecules (Lofgren & Hellden, 2008). However, especially at younger ages, students do not often recognize water as an invisible gas in the air (Bar, 1989; Bar & Travis, 1991; Cho & Anderson, 2006; Osbourne & Cosgrove, 1983). Similarly, students have difficulty tracing water vapor back to liquid water. Students often do not recognize that the water that condenses on a glass or in a cloud comes from the invisible water vapor in the air.

There also has been some work conducted to explore children's understanding of substances in water. Research related to water quality has examined children's understandings of pollution and sources of pollution. Brody (1991) found that by 4th-grade students think of pollution as stuff that people throw on the ground. By 8th-grade, students' definitions of pollution include chemicals. By 11th-grade, students begin to understand that pollution can have more than one source, its effects are based on concentration, and that air, land, water, and living systems are interconnected. The finding that middle level students define pollution in terms of chemicals is an interesting one. Related research has shown that many students as well as adult teachers hold informal conceptions about chemicals, often defining chemicals as artificial, poisonous and dangerous substances, rather than defining chemicals as all substances that have mass (Salloum & Boujaoude, 2008).

The present study takes the viewpoint that students' understanding as part of a coherent and robust way of looking at the world. Students' views are rooted in their folk discourses (Bruner, 1996) and helping them make sense of their world and experiences is our purpose of school science teaching and learning. Students' views of the world and ways of reasoning about their experiences, however, differ in important ways from the scientific reasoning about materials in systems that represent formal school science discourses. The goal of this research is to better characterize students' folk discourse about water in various water systems and understand how they learn a new secondary Discourse that relies on model-based reasoning about water in connected systems.

## Ⅲ. Method

### Participants

This study was realized during the spring semester of 2010 academic year with the participants of 123 Seoul Global high school 10th grade students whose characteristics are described in Table 1. The school is located in a public sector whose population character is distinct in terms of academic achievement particularly in humanities and social sciences.

### Instruments

We obtained Korean high school students' responses from the administration of two tests: Environmental Science Literacy for Water test and the Revised New Ecological Paradigm scale.

### Environmental science literacy for water (ESLW) test

Table 1. Demographic characteristics of participants

| Characteristic | | Number (%*) |
|---|---|---|
| Gender | Male | 37 ( 30) |
| | Female | 86 ( 70) |
| Grade level | 10th | 123 (100) |
| Date of Birth | 1993 | 6 ( 5) |
| | 1994 | 117 ( 95) |
| | 1995 | 2 ( 2) |
| Hometown | Rural area | 3 ( 2) |
| | Small town | 37 ( 30) |
| | Big city | 55 ( 45) |
| | Metropolitan city | 28 ( 23) |

* Percent values are rounded off to the integer.

Table 2. Dimensions of environment science literacy for water test

| Dimension | Item number | Question type |
|---|---|---|
| Fresh water supply | 1 | Multiple choice |
| Distribution of water | 2~5 | Multiple choice |
| Environmental problems | 6 | 5-point Likert scale |
| Managing water crisis | 7 | 5-point Likert scale |
| Properties of water | 8~17 | True/false |

The ESLW test is designed by the authors in order to determine the participants' understanding of basic water properties and water quality in socio-ecological systems in which human-engineered and natural system interact each other and is consisted of 8 multiple choice questions, 2 five-point Likert-scale questions, and 10 true/false questions. The five dimensions of the water science literacy examined are fresh water supply, distribution of water, environmental problems, managing water crisis, and properties of water (Table 2).

### The revised NEP scale

Since many attempts to measure the relationship between environmental attitudes and environmental knowledge, the NEP scale designed by Dunlap and Van Liere (1978) has been the most frequently used tool. We adopted the revised NEP scale in the form of five-point Likert scale that is apt to our study. Likert-type surveys are the most common when it comes to obtaining quick information, they are easy to assess and, if they are made with the established requisites, they can faithfully fulfill the role for which they are designed (DeVellis, 1991). The revised NEP scale measures five components of attitudes toward environment; the reality of limits to growth, anti-anthropocentrism, the fragility of nature's balance, rejection of exemption, and the possibility of eco-crisis (Table 3).

Table 3. Principal components of the revised NEP scale

| The Revised NEP | Item numbers |
|---|---|
| The reality of limits to growth | 1, 6, 11 |
| Antianthropocentrism | 2, 7, 12 |
| The fragility of nature's balance | 3, 8, 13 |
| Rejection of exemption | 4, 9, 14 |
| The possibility of eco-crisis | 5, 10, 15 |

### Data Analysis

As part of design-based research, we developed criteria to help us determine how to revise and adjust the assessments for environmental science literacy for water and attitudes toward environment related to it throughout the study. As Niaz (2008) asserted, conceptual coherence, compatibility with current research and empirical criteria are the three quality guidelines that led to the credibility of our theoretical framework and empirical validation process. Throughout the pilot study conducted in the previous academic year, we determined five dimensions of environmental science literacy for water questions and the following questionnaires for this study and decided to adopt the revised NEP scale as measures of attitudes toward environment because of its pro-environmental components that concerns natural resources like water, which is very apt to our study. The content analysis from the interviews and students' written assessments and worksheets from teaching experiments for pilot study aimed to provide underlying themes and issues for the development of the survey questions in the present study. Quantitative data analysis methods were followed for analyzing participants' responses on the surveys. In order to identify the level of high school students' environmental science literacy for water, frequencies were determined through descriptive statistics.

## Ⅳ. Results

### Environmental Science Literacy for Water (ESLW) Test

#### Fresh water supply profile

Students were made to answer a multiple choice question about fresh water supply in terms of drinking water conditions. As presented in Table 4, regarding the biggest water problem for the next decade, more than half of the students (58%) were concerned about water shortage mostly than water pollution and drinking water quality problems. One interesting finding was students were not much aware of water infrastructure such as drinking water treatment plants, sewer lines, drinking water distribution lines, and storage facilities.

#### Environmental concerns profile

Table 4. Percentages of response to fresh water supply items

| Item | % response* (f=123) |
|---|---|
| What do you think is the world's biggest water problem in the next decade? | |
| We will not have enough water | 58 |
| Water will be too polluted | 29 |
| Drinking water will be unsafe | 12 |
| Water systems/infrastructure will break down | 1 |

* Percent values are rounded off to the integer.

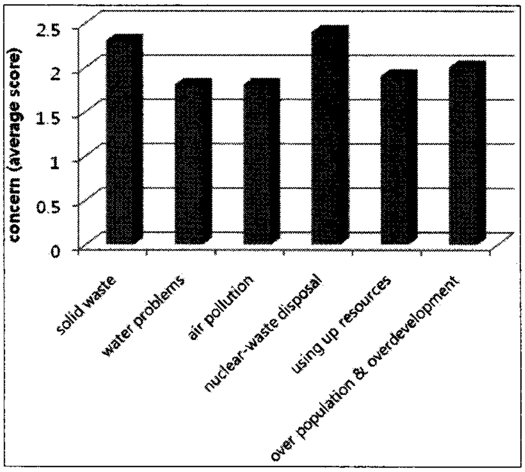


Figure 1. Students' responses for environmental concern items.

The target for this section of the questionnaire was to find out the degree of concern of the students about the sources of environmental problems. The students' concern about environmental problems were evaluated using five-point Likert scale and estimated into the average score of 123 participants for each question. The score was measured from 1 to 5 with more concerns by increasing numbers. The average score given by the students are presented in the Figure 1 below.

As was displayed in the Figure 1, high school students are not very much concerned about the presented environmental problems that average score of their concern was below half of the full score (2.5) in minimum 1 to maximum 5 scoring system. Among six of the environmental concerns, water problems rated the lowest in this profile.

## Water Crisis Measures Profile

The target of the managing water crisis items was to assess students' responsibility toward the water problem and intention to be a part of responsible environmental behavior. The answers for the items of the survey test reflect students' responsibility toward water problems. As Table 5 displays, more than half of them show their awareness on responsibility in dealing with water problems by agreeing with the item components 'encourage water conservation' and 'find new supplies' by high average scores. Interestingly enough, the average scores in every item components in water crisis measures profile are higher than the environmental problem concerns profile, reflecting that students are more aware of the necessity of controlling the environmental behavior than they are conscious of their own responsibility on producing environmental problems.

## The Distribution of Water Profile

The questions in this section explores whether

Table 5. Average scores to managing water crisis item components

| Item | Average score* (f=123) |
|---|---|
| What measures would you use to handle your water crisis? | |
| Mandatory restrictions on water use | 2.1 |
| Find new supplies | 3.5 |
| Raise the price of water | 2.6 |
| Cut back new developments | 2.4 |
| Encourage water conservation | 4.3 |
| Buy water from another city/state | 2.3 |

* The score is an average value in 5-point Likert scale, scored from 1 to 5 and rounded off to the first decimal point.

students have a basic awareness of the global distribution of fresh water. Although a large quantity of water covers much of the surface of the Earth, very little of that water is fresh water that is available for use by humans and other terrestrial organisms. Particularly, we are interested in students' awareness of the fact that most fresh water on Earth is found in frozen form around the North and South Poles and is therefore unavailable for use by plants and animals in most terrestrial ecosystems. Another query in this section is to understand students' awareness that water is a major component of our bodies, and that we depend on water for survival. Humans can live more than a month without eating food, but if we do not take in liquids, we die in a few days. According to the results shown in Table 6, large percentages of the respondents were aware of the water ratio on Earth (89%) but only slightly over half of the students were aware that the fresh water supply is just 3 % of the water on Earth. Considering the fact that drinkable fresh water is below 1 %, another 30 % of the students who answered 1 % were quite close to the factual knowledge about fresh drinking water. The most confusing fact to the students were the fact that most fresh water on Earth is found in frozen form around the North and South Poles and only one-fourth of the students were aware it. More than half of the students regarded rivers and lakes as the water body that contains most of the Earth's fresh water.

Table 6. Percentages of response to distribution of water items

| Item | % response* (f=123) |
|---|---|
| About what part of the Earth's surfaces is covered with water? | |
| 30 % | 0 |
| 55 % | 2 |
| 75 % | 89 |
| 90 % | 9 |
| About what percentage of the water on Earth is fresh water? | |
| 1 % | 30 |
| 3 % | 52 |
| 12 % | 12 |
| 20 % | 6 |
| Where and in what form is most of the fresh water on the Earth found? | |
| Ice caps and glaciers | 25 |
| Oceans | 2 |
| Rivers and lakes | 56 |
| Underground | 17 |
| About how much of your body is made up of water? | |
| 95 % | 20 |
| 60 % | 78 |
| 35 % | 2 |
| 6 % | 0 |

* The score is an average value in 5-point Likert scale, scored from 1 to 5 and rounded off to the integer. Correct answers are written in bold letters.

## The Properties of Water Profile

This section targeted examination of our students' basic understanding about physical and chemical properties of water and the result of the inquiry is shown in the Table 7. Students' knowledge about the topics of molecular structure of water and ice (item number 1, 83 %), surface tension of water (item number 2, 89 %), acidity of rainwater (item number 5, 92 %), basicity of seawater (item number 8, 87 %), vapor pressure depression (item number 10, 76 %) recorded very high ration as shown in the table. Students showed moderate understanding in molal boiling point elevation constant of water and the heat accompanied by phase changes (item number 6, 50 %),

Table 7. Percentages of correct responses to the properties of water items

| Item | % correct response* (f=123) |
|---|---|
| 1. Water contracts when it freezes. | 83 |
| 2. Water has a high surface tension. | 89 |
| 3. Condensation is water coming out of the air. | 7 |
| 4. More things can be dissolved in sulfuric acid than in water. | 6 |
| 5. Rainwater is the purest form of water. | 92 |
| 6. It takes more energy to heat water at room temperature to 100℃ than it does to change 100℃ water to steam. | 50 |
| 7. If you evaporate a 200mL glass full of water from the Great Salt Lake with a salinity of about 20% by weight, you will end up with a salt cubic with about 3.4cm edges. | 63 |
| 8. Sea water is slightly more basic (the pH value is higher) than most natural fresh water. | 87 |
| 9. Raindrops are tear-shaped. | 57 |
| 10. Water boils quicker at Daegu, Kyungbuk than at the beach. | 76 |

* Percent values are rounded off to the integer.

percentage weight concentration of aqueous solution and salinity of water (item number 7, 63 %), and the shape of raindrops and surface tension of water (item number 9, 57 %). However, one of the water cycle processes, condensation was not easy topic for the subjects in this study. The percentage of correct answer was just 7 % (item number 3). This was surprising that they couldn't apply this question to the phenomenon that they had often observed in winter. The water drops that formed on the outside of a cold glass or on the inside of a window are actually liquid water condensing from water vapor in the air. This result is interesting in that despite of all the good scores in other areas of water properties in this test, students appeared to have the same traditional misunderstanding that conceptual change researchers have reported (Bar, 1989; Cho & Anderson, 2006; Lofgren & Hellen, 2008). Cho and Anderson (2006) reported in the study of American high school students' understanding of matter transformation in physical and chemical changes that students had difficulties in tracing matter in its invisible form. The Korean counterpart, our participants, also showed lack of understanding of invisible part of matter transformations in water systems during phase changes. Furthermore, students thought of sulfuric acid as better solvent than liquid water, which is not true. Only 6 % of the students answered correctly, the lowest value of all the items in this profile. Actually it can dissolve more substances than any other liquid. The water we see in rivers, lakes, and the ocean may look clear, but it actually contains many dissolved elements and minerals, and because these elements are dissolved, they can easily move with water over the surface of the earth.

## Attitudes toward Environment

Attitudes toward Environment items used in the survey were adopted from the Revised NEP scale as mentioned previously in the research background and method sections. As Table 8 displays,

Table 8. Average score of the revised NEP scale

| Principal component | Item number | Sum | Average score* ($f$=123) |
|---|---|---|---|
| The reality of limits to growth | 1, 6, 11 | 1,288 | 3.6 |
| Antianthropocentrism | 2, 7, 12 | 1,381 | 3.7 |
| The fragility of nature's balance | 3, 8, 13 | 1,347 | 3.7 |
| Rejection of exemption | 4, 9, 14 | 1,197 | 3.2 |
| The possibility of an eco-crisis | 5, 10, 15 | 1,476 | 4.0 |
| Total | | 6,689 | 3.6 |

* The score is an average value in 5-point Likert scale, scored from 1 to 5 and rounded off to the first decimal point.

all the components of attitudes toward environment were recorded high in average and showed students' strong pro-environmental attitude. Particularly, students took the possibility of eco-crisis as the most serious condition to pat attention to. Contrasting this result to the environmental concern component of water science literacy profile in this study, a highly interesting difference from the result of environment concern measures in WSLS can be found as in Figure 1. Researching of the Korean middle school students' awareness of water deficiency, the experiencing of it and the attitude of water use, Kwak and Lee (2005) found severe gap between those variables. The middle school students were aware of the water deficiency problem (39.5 % very severe, 57 % severe) and said water is an important resource (very important 89.2 %, important 10.8 %) but they revealed that they waste water resource quite a lot (waste water a lot 8.7 %, waste water quite a lot 64.7 %). It seems that to shorten the gap between water science literacy and the actualization of it is beyond our hope and that's what we, educators need to consider in curriculum organization and teaching and learning of science in our K-12 schools.

## V. Discussion and Implications

Many of the subjects in this study had quite a good understanding about water distribution on Earth except in the case of fresh water distribution. They also favored filtered water over other water sources from human-engineered and natural water systems as drinking water but were not correspondingly aware of the infrastructure of water systems. They considered water shortage the most serious water-related problem of the near future. Of the given environmental problems, they cared most about nuclear-waste disposal most among the environmental problems exemplified, but this dimension didn't obtain higher average scores than the water crisis profile from the ESLW test results. That is, the participating high school students did not have clear experiential perception of water crisis, only abstract emotional responses to preparing for water shortage problems by encouraging others to conserve water. This result is quite similar to the result of the study about the big gap between Korean middle school students' perceptions of the necessity of water conservation and their practical behavior in terms of water conservation in actuality.

Despite the limitations of the present study in terms of the location and type of the participant school, the authors would like to address the following: in contrast to the incorporation of some other environmental issues such as global warming and ozone depletions into high school science curriculum, the water unit has been omitted and remained subsidiary in our nation's school science curriculum. Our study suggests curriculum incorporation of water-related issues in high school to encourage students' environmental knowledge and attitudes regarding water and water quality issues is necessary for enhancing students' democratic citizenry and informed decision making in a 21st century globalized world. This study further guides our understanding of the relationship between interdisciplinary environmental science teaching and students' learning of environmental knowledge and attitudes toward the environment.

## References

1. Abramson, P. R. & Inglehart, R. (1995). *Value Change in Global Perspective*, University of Michigan Press, Ann Arbor, MI.
2. Anderson, C., Sharma, A., Mohan, L., Cho, I. & Jin, H. (2006). Developing learning progressions toward environmental literacy, *Paper presented at the Conference of the National Association for Research in Science Teaching*, San Francisco, CA.
3. Arcury, T. A. & Christianson, E. H. (1993). Rural-urban differences in environmental knowledge and actions, *The Journal of Environmental Education, 25(1)*, 19-25.
4. Bar, V. (1989). Children's views about the water cycle, *Science Education, 73(4)*, 481-500.
5. Bar, V. & Travis, A. S. (1991). Children's views concerning phase changes, *Journal of Research in Science Teaching, 28(4)*, 363-382.
6. Belchior, A. M. (2010). Are green political parties more post-materialistic than other parties? *European Societies*, First published on: 25 June 2010 (iFirst).
7. Blank, L. & Brewer, C. (2003). Ecology education when no child is left behind, *Frontiers in Ecology and the Environment, 1(7)*, 383-384.
8. Brody, M. J. (1991). Understanding of pollution among 4th, 8th, and 11th grade students, *Journal of Environmental Education, 22(2)*, 24-33.
9. Bruner, J. S. (1996). *The Culture of Education*, Harvard University Press.
10. Bybee, R. W. (2003). Ecology education when no child is left behind-Forum response, *Frontiers in Ecology and the Environment, 1(7)*, 389-390.
11. Cho, I. (2007). Carbon cycle learning progressions for K-12 in Korea and the U.S., *Paper presented at the Annual Meeting of National Association for Research in Science Teaching*, New Orleans, LA.
12. Cho, I. & Anderson, C. W. (2006). Understanding of matter transformations in physical and chemical changes, *Paper presented at the Annual Meeting of the National Association for Research in Science Teaching*, San Francisco, CA.
13. Covitt, B. A., Gunckel, K. L. & Anderson, C. W. (2009). Students' developing understanding of water in environmental systems, *Journal of Environmental Education, 40(3)*, 37-51.
14. Coyle, K. (2005). *Environmental Literacy in America*, The National Environmental Education & Training Foundation, Washington D.C.
15. DeVellis, R. F. (1991). Scale Development: Theory and applications, *Applied Social Research Method Series* (Vol. 26), Newbury Park, CA.
16. Dunlap, R. E. & Van Liere, K. D. (1978).

The new environmental paradigm: A proposed measuring instrument, *The Journal of Environmental Education, 9(3)*, 10-19.

17. Dunlap, R. E., Van Liere, K. D., Mertig, A. D. & Jones, R. E. (2000). Measuring endorsement of the new ecological paradigm: a revised NEP scale, *Journal of Social Issues, 56(3)*, 425-442.
18. Eagly, A. H. & Kulesa, P. (1997). Attitudes, attitude structure, and resistance to change. Implications for persuasion on environmental issues, In Bazerman, M. H., Messick, D. M., Tenbrunsel, A. E. & Wade-Benzoni K. A. (Eds.), *Environment, Ethics, and Behavior: The Psychology of Environmental Valuation and Degradation* (pp. 122-153), The New Lexington Press, San Francisco, CA.
19. Inglehart, R. (1977). *The Silent Revolution: Changing Values and Political Styles among Western Publics*, Princeton University Press, Princeton, NJ.
20. Kwak, T. & Lee, D. (Feb. 2005). (in Korean). An exploration of environmental education practices regarding water shortage, *Proceedings of the Korean Association of Environmental Education.*
21. Lofgren, L. & Hellden, G. (2008). Following young students' understanding of three phenomena in which transformations of matter occur, *International Journal of Science and Mathematics Education, 6*(3), 481-504.
22. Ministry of Education, Science and Technology (2009). *Proclamation of the National Science Curriculum Standards 2009-41* (Vol. 9).
23. Ministry of Education and Human Resources development (2007). *Proclamation of the National Science Curriculum Standards 2007-79* (Vol. 9).
24. Ministry of Education (1997). *Proclamation of the National Science Curriculum Standards, 1997-15* (Vol. 5).
25. Niaz, M. (2008). A rationale for mixed methods (integrative) research programmes in education, *Journal of Psychology of Education, 42(2)*, 287-305.
26. Osbourne, R. J. & Cosgrove, M. M. (1983). Children's conceptions of the changes of state of water, *Journal of Research in Science Teaching, 20(9)*, 825-838.
27. Pickett, S. T. A., Kolasa, J. & Jones, C. G. (1994). *Ecological Understanding*, Academic Press, San Diago, CA.
28. Presidential Committee on Green Growth. (January 13, 2010). Act No 9931: *Framework Act on Low Carbon, Green Growth*, http://www.greengrowth.go.kr/english/en_information/en_report/userBbs/bbsView.do
29. Salloum, S. & BouJaoude, S. (2008). Careful! It is $H_2O$? Teachers' conceptions of chemicals, *International Journal of Science Education, 30(1)*, 33-64.
30. Taiwo, A. A., Ray, H., Motswiri, M. J. & Masene, R. (1999). Perceptions of the water cycle among primary school children in Botswana, *International Journal of Science Education, 21(4)*, 413-429.

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