Glimpses of Climate Literacy:
Climate Literacy as Assessed Partially by a Limited Set of Items from
Four Recent National Assessments of Environmental Literacy

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Abstract

To date, there has not yet been a national assessment of, or a systematic review of evidence from different studies pertaining to, climate literacy among K-14 aged learners. This was one of a number of needs explored at a Workshop on Climate Change Education sponsored by the National Academies in late August 2011. In an attempt to begin to address this need for evidence, Dr. Marcinkowski was invited to prepare a presentation and paper for that Workshop. In turn, he invited colleagues who had been involved in recent national assessments of environmental literacy to work with him. In historical order, these national assessments were conducted in Korea (Grades 3, 7, & 11), Israel (Grades 6 & 12), the U.S. (Grades 6 & 8) and Turkey (Grade 5). Each of these assessments included measures of environmental knowledge, dispositions, skills, and behavior. Using material presented in *Climate Literacy: The Essential Principles of Climate Science* (U.S. GCRP/CCSP, 2009), the authors identified a total of 109 items from their measures that were related to climate literacy. Results for these items, and for the measures from which they were drawn, were charted and analyzed. Analyses focused on three questions: (1) what the results for these items and measures had to say about climate literacy in *each nation*; (2) what the results for these items and measures had to say about climate literacy in *different grade levels*; and (3) what these results had to say about item-specific features of climate literacy *across nations and grade levels*. Results pertinent to each question are presented and discussed in successive sections. In the closing discussion, the authors: review the purpose, delimitation, and limitations apparent in this paper; summarize findings pertinent to each of these questions; and pose a series of research recommendations pertinent to the need for evidence regarding the status of climate literacy in the K-14 sector.

Introduction

The scientific community has been generating, reviewing, and summarizing evidence of changes within Earth's climate system, including the causes and effects of those changes, for several decades. This growing body of evidence points to increases in atmospheric CO_2 and other greenhouse gasses, increased surface temperatures, and to the influence of human activities on these (IPCC, 2007a, 2007b, 2007c, 2007d; National Academies, 2008). Despite widespread agreement among scientists, there has been visible resistance to this evidence within the public and private sectors. However, evidence from this same period regarding public perceptions of and opinions about global warming and climate change has been limited when compared to this growing scientific body of evidence (Weber & Stern, 2011). Nonetheless, recent surveys by a Pew Research Center (2009), and by the Yale Project on Climate Change and the George Mason University Center for Climate Change Communications (Leiserowitz, Maibach, & Roser-Renouf, 2008; Maibach, Roser-Renouf, & Leiserowitz, 2009) have shed significant light on a number of societal- and policy-relevant conditions.

Context, Problem and Purpose

More recently, the National Academies expanded its attention to include climate change education (K-14), in effect asking "What do we know about climate change education within the formal education sector (K-14)?". To shed light on this question, the Science Education Board of the National Academies formed a Steering Committee to plan and convene a Workshop on Climate Change Education in late August 2011. This Workshop was designed to explore a variety of questions, including the nature and extent of climate change education in this sector, the breadth and depth of existing programming, the quality of available materials, evidence of student perceptions and program effects, overall quality, and apparent gaps and needs.

One of the concerns raised by the workshop planners pertained to apparent limitations in the available evidence regarding the status of climate literacy among K-12 or K-14 youth. This concern reflected the fact that there have not been any surveys of this population comparable to those conducted among adults within the U.S., as noted above. As a result, planners invited

several to prepare and present summaries of evidence from other sources. Dr. Eddie Boyes was invited to present the evidence he and his colleagues have been accumulating over the past decade from nearly 13,000 students in 11 countries on these students' understanding, or mental models, of climate change (Boyes, 2011). Similarly, Dr. Marcinkowski was invited to present what he and his colleagues were able to draw from four recent national assessments of environmental literacy. As this team prepared to present the results of these secondary analyses, they realized that similar a secondary analysis of the PISA 2006 Science Assessment data could be conducted, due to the inclusion of items on climate change in that assessment (OECD, 2006, 2009). Beyond these sources of evidence, there are others, such as data on climate change (and influenza) gathered during 2009 as part of the ongoing Longitudinal Study of American Youth (Miller, 2010). Thus, while there have been no comprehensive surveys of K-14 youth on climate change within and outside of the U.S., there are results and additional sources of data that can be used to begin to construct a reasonably sound understanding of the status of students' perceptions, knowledge, dispositions, skills or competencies, and actions related to climate change.

In an attempt to address the need for this type of evidence, Dr. Marcinkowski and his colleagues prepared a Workshop presentation and this paper to summarize evidence pertaining to climate literacy variables drawn from four recent national assessments of environmental literacy. More specifically, they were asked to present and summarize evidence from these national assessments in response to three questions:

1. What do select items from four National Assessments of Environmental Literacy (U.S., Korea, Israel, and Turkey) suggest about the current state of climate literacy?

2. What differences appear to exist between younger and older students?

3. Do there appear to be differences in the status of climate literacy, as measured by a limited set of common indicators, between countries?

Methods

Overview of the national assessments and associated data sources. As noted above, data pertaining to climate literacy were drawn from recent four national assessments of environmental literacy. Information pertinent to each of these assessments and data sets is summarized in Table 1, below.

Table 1. Information about Sources of National Assessment Data

	National Assessments			
Information about Data Sources	Korea	Israel	U.S.	Turkey
Assessment Period	2002-03	2004-06	2006-08	2007-09
Grades (Sample Sizes)	3rd (969) 7th (987) 11th (1,037)	6th (1,591) 12th (1,530)	6th (1,042) 8th (962)	5th (2,412)
Reports	Shin et al., 2005; Chu et al., 2005	Tal et al., 2007; Negev et al., 2008	McBeth et al., 2008, 2010	Erdogan, 2009; Erdogan & Ok, 2011

As indicated in Table 2 (p. 5), the research team responsible for designing, conducting, and reporting each of these national assessments consulted a number of source documents pertaining to environmental literacy (Marcinkowski, et al., in press). Despite differences in these sources documents, they all include environmental literacy components in four domains of learning outcomes: (a) knowledge; (b) affective dispositions; (c) cognitive skills; and (d) behavior. The specific components of environmental literacy in these domains that were included in each of these national assessments are also identified in Table 2 (p. 5).

Methods used to identify relevant items in national assessment instruments. A number of steps were taken by the team to identify and select items for inclusion in these secondary analyses due to the fact that only a subset of items in each had any relationship to change. In the first step, team members translated into English all items in the each grade-

Table 2. Environmental Literacy Frameworks and Components Reflected in These National Assessments

	National Assessments			
Environmental Literacy	Korea	Israel	U.S.	Turkey
Primary Documents Consulted	Simmons (1995)	Simmons (1998); Hungerford & Volk (1990); Marcinkowski (1998)	Wilke (1995)	Simmons (1995); Volk & McBeth (1997)
Components Assessed				
A. Knowledge				
• Ecological Knowledge	√	√	√	√
• Environmental Knowledge	√	√		√
B. Affective Dispositions				
• Environmental Sensitivity	√	√	√	√
• Environmental Feelings		√	√	
• Environmental Attitudes	√	√		√
• Personal Responsibility	√	√		
• Locus of Control/ Efficacy	√	√		
• Verbal Commitment/ Willingness	√	√	√	√
C. Cognitive Skills	√		√	√
D. Behavior	√	√	√	√

specific survey used in each of these national assessments (i.e., Noh: Korean to English; Negev and Sagy: Hebrew to English; and Erdogan: Turkish to English). These translations were circulated to all team members to facilitate communication and consistency in item selection.

The second step involved the specification of a common framework to guide the analysis and selection of items. Marcinkowski prepared this framework using *Climate Literacy: The Essential Principles of Climate Science* (U.S. Global Change Research Program/Climate Change Science Program, 2009). The elements of this framework were drawn from three sections of this document, and are identified below.

A. Climate Literacy Goals. A climate literate person:

1. understand the essential principles of Earth's climate system;
2. knows how to assess scientifically credible information about climate;
3. communicate about climate change in a meaningful way; and
4. is able to make informed and responsible decisions with regard to actions that may affect climate. (p. 3)

B. Essential Principles of Climate Literacy.

1. The sun is the primary source of energy for Earth's climate system;
2. Climate is regulated by complex interactions among components of the Earth System;
3. Life on Earth depends on, is shaped by, and affects climate;
4. Climate varies over space and time through both natural and man-made processes;
5. Our understanding of the climate system is improved through observation, theoretical studies, and modeling;
6. Human activities are impacting the climate system; and
7. Climate change will have consequences for the Earth System and human lives. (pp. 9-15)

C. Guiding Principles for Informed Climate Decisions.

1. Climate information can be used to reduce vulnerabilities or enhance resilience of communities and ecosystems affected by climate change;
2. Decisions that involve Earth's climate must be made with an understanding of the complex interactions among physical and biological components of the Earth System, as well as the consequences of such decisions on social, economic, and cultural systems;
3. The impacts of climate change may affect the security of nations;
4. Humans may be able to mitigate climate change or lessen its severity by reducing greenhouse gas concentrations;
5. A combination of strategies is needed to reduce greenhouse gas emissions (immediate: conservation; short-term: switching from carbon intensive to renewable energy sources; long-term: research and fundamental change in the way humans use energy);
6. Humans can adapt to impacts by reducing their vulnerability to its impacts; and
7. Actions taken by individuals, communities, states, and countries all influence climate. (p. 6)

In the third step, this framework was used to analyze and identify items in instruments used in each national assessment. To accomplish this, this framework was presented in the left column of a MicroSoft Excel file, and the various sections of the instrument used to survey students in each grade within each national assessment were presented in a series of columns to the right. Within this analysis matrix, each team member was asked to insert the item number for each item from their national assessment instrument(s) that appeared to correspond to the elements of this framework. These charts were circulated to other team members for review and comment to ensure consistency in the selection of items across these analyses. Final decisions regarding

items deemed to be directly related to elements of this framework were made by Noh and Marcinkowski, with review and approval by Erdogan and Sagy. The results of the procedures used to analyze and identify items are summarized in Table 3, below.

Table 3. The Number of Items Deemed to be Directly Related to Climate Literacy from National Assessment Instruments, by Grade Level

Grade Levels	Elementary		Middle			Secondary	
National Assessment	Korea	Turkey	Korea	Israel	U.S.	Korea	Israel
Grades	3	5	7	6	6, 8	11	12
Major Environmental Literacy Components							
A. Knowledge	5	8	10	8	2	5	9
B. Affective Dispositions	5	2	6	4	5	6	3
C. Cognitive Skills		2					
D. Behavior	5	5	5	2	4	6	2

Due to the fact that only two cognitive skill items from one of these national assessments were directly related directly to elements of climate literacy, these items were dropped from this analysis. Therefore, only items used to measure (A) Knowledge, (B) Affective Dispositions, and (D) Behavior, were included in further analyses and will be reported in this paper.

Methods used to prepare results for selected items. For Question 1, team members were asked to present results from each of the four national assessments. The only comparisons to be made will be between or among grades within each national assessment. To accomplish this, team members decided to prepare and report the results for selected items in three ways: (1) to calculate and report either the percent of students who responded correctly to each selected knowledge item, or the mean score for students on each affective disposition or behavior item; (2) to report the overall score for each scale in which selected items appeared so as to provide information about results for the full set of items against which results on each selected items could be compared; and (3) to translate mean score on affective disposition and behavior scales into a overall item mean scores so to as facilitate the comparison of overall scale and individual

item scores (i.e., by dividing the overall scale score by the number of items in that scale). The results for these selected items for each grade within each national assessment were organized into tables for reporting purposes.

For Question 2, team members were asked to summarize results for younger and older students across national assessments. To accomplish this, team members organized and summarized the result for Question 2 into three grade levels: (a) elementary students, including result for third graders from Korean and fifth graders from Turkey; (b) middle grades students, including results for sixth graders from Israel, seventh graders from Korea, and sixth and eighth graders from the U.S.; and (c) secondary students, including results for eleventh graders from Korea and twelfth graders from Israel. The only comparisons made were between or among national samples within each of these grade levels. These comparisons were summarized in narrative form, drawing on results presented in the tables prepared for Question 1.

For Question 3, team members were asked to draw comparisons on common or closely related items pertaining to features of climate change across national assessments and grades. Due the fact that these national assessments had few items in common, team members selected and used items with closely related content as the basis for this general comparison. To accomplish this, results for closely related items within each of the three major components of environmental literacy (i.e., Knowledge, Affective Dispositions, and Behavior) were organized and compared. The results of these comparisons also were organized into tables for reporting purposes.

Results

Results for Question 1: Climate literacy results from each national assessment.

Climate literacy results from the national assessment in Korea, by grade level. The results of the analysis of selected items in the instrument used to assess third graders in Korea are summarized in Table 4 (p. 9). Of 24 items in the Knowledge test, five were directly related to climate literacy. The percent of students who answered these five items correctly ranged from 39.6% to 97% (i.e., from low to high). The percent correct for three of these five items was greater than the percent correct for the 24-item Knowledge scale (61.8%). These results indicated

Table 4. Results for Selected Items from the 3rd Grade Assessment in Korea, by Component

Components	Items	% Correct or Mean
Knowledge	Total, Knowledge Scale (24 items)	61.8
	K13. Energy source of plants	39.6
	K15. Source of oxygen in the air cycle	97.0
	K17. Identifying recycle symbols	52.4
	K18. Non-recyclable/reusable items	72.2
	K19. Ways to improve air quality	95.1
Affective Dispositions	Total, Affective Scale (22 items)[1]	50.12 (3.06)[2]
	A8. Importance of air and water quality (A)	3.59
	A12. Recycle aluminum cans (A)	3.13
	A16. Walk short distance instead of taking car (W)	3.42
	A20. Drive a big family car (A)[3]	3.17
	A21. Leave the lights on in an empty classroom (R)[3]	2.96
Behavior	Total, Behavior Scale (16 items)	49.94 (2.79)[4]
	B3. Walk, take public transportations, or ride bike instead of using a car	2.82
	B5. Put aluminum cans on the ground into recycle bin	2.84
	B7. Collect cups, containers, or bags for reusing later	2.77
	B9. Use both sides of paper when drawing or writing	3.00
	B11. Turn off the lights when leave a room	3.35

[1] A: Environmental Attitude, W: Willingness, R: Personal Responsibility
[2] Mean scores fall along a 4-point scale: 1=strongly disagree; 2=disagree; 3=agree; and 4=strongly agree. Standard scores ranged from 0 - 100.
[3] The responses were reverse scored.
[4] Mean scores fall along a 4-point scale: 1=never; 2=rarely; 3=sometimes; and 4=always. Standard scores ranged from 0 - 100.

that the third graders were more knowledgeable about atmospheric conditions (e.g., sources of oxygen, ways to improve air quality) than about sources of energy for plants. For the Affective scale and Behavior scale, the mean for each scale was divided by the number of items to arrive at an *overall item mean*. Of 22 Affective items, five were directly related to climate literacy. The item mean for four of these five items was greater than for this scale's overall item mean (M = 3.06; slightly above "agree"), indicating reasonably strong attitudes toward air and water quality, and a reasonably strong willingness to reduce greenhouse gas emissions. The remaining item was negatively worded (reverse scored), which could have influenced these results. Of 16 items in the Behavior scale, five were directly related to climate literacy. The item mean for four of these five items was greater than the overall item mean (M = 2.79; slightly below "sometimes"). Overall, the third graders' responses indicated that their level of energy conservation was greater than their level of recycling.

The results from the analysis of selected items in the instrument used to assess seventh graders in Korea are summarized in Table 5, below. Of 27 items in the Knowledge test, 10 were directly related to climate literacy. The percent of student who answered these 10 items correctly ranged from 21.7% to 75% (i.e., from low to moderate). The percent correct for only three of these 10 items was greater than the percent correct for the 27-item scale (62.4%). However, as with the

Table 5. Results for Selected Items from the 7th Grade Assessment in Korea, by Component

Components	Items	% Correct or Mean
Knowledge	Total, Knowledge Scale (27 items)	62.4
	K5. Original source of energy for all living things	48.6
	K7. Solar energy use by producers	53.2
	K8. Source of oxygen in the atmosphere	65.3
	K9. Water cycle	55.8
	K17. The main cause of earth's temperature change	53.3
	K18. The cause of holes in the stratospheric ozone	75.0
	K22. Use of fossil fuel as an energy source	55.0
	K24. Recycled paper	37.5
	K25. Example of non-renewable resources	66.9
	K27. Ways to solve solid waste problem	21.7
Affective Dispositions	Total, Affective Scale (27 items)[1]	50.18 (2.83)[2]
	A5. Recycle aluminum cans (A)	2.64
	A10. Government's role to encouraging people to drive energy efficient cars (A)	2.51
	A18. Walk short distance instead of taking car (W)	3.12
	A19. Wear warm underclothes in winter to save energy (W)	2.60
	A25. Leave the lights on in an empty classroom (R)[3]	2.83
	A26. Drive a big family car (A)[3]	2.97
Behavior	Total, Behavior Scale (25 items)	49.72 (2.42)[4]
	B3. Walk, take public transportations, or ride bike instead of using a car	2.88
	B5. Put aluminum cans found on the ground into recycle bins	2.32
	B7. Collecting cups, containers, or bags for later reuse	2.33
	B9. Use both sides of paper when drawing or writing	3.06
	B11. Turn off the lights when leaving a room	3.44

[1] A: Environmental Attitude, W: Willingness, R: Personal Responsibility
[2] Mean scores fall along a 4-point scale: 1=strongly disagree; 2=disagree; 3=agree; and 4=strongly agree. Standard scores ranged from 0 - 100.
[3] The responses were reverse scored.
[4] Mean scores fall along a 4-point scale: 1=never; 2=rarely; 3=sometimes; and 4=always. Standard scores ranged from 0 - 100.

third-grade sample, seventh graders were more knowledgeable about some atmospheric conditions (i.e., causes of ozone holes, sources of oxygen) than others (e.g., causes of temperature change), and about solid waste problems and solutions. For the Affective scale and the Behavior scales, each scale mean was transformed into an *overall item mean*. Of 27 Affective items, six were directly related to climate literacy. The mean score on two of these six items was greater than for this overall item mean (M = 2.83; slightly below "agree"), pointing to stronger dispositions toward modes of transportation other than cars, and more moderate dispositions toward residential energy conservation and recycling. Of 25 items in the Behavior scale, five were directly related to climate literacy. The mean score on three of these five items was greater than the overall item mean (M = 2.42; between "rarely" and "sometimes"). As with the third grade sample, these seventh graders' responses indicated that level of energy conservation was greater than their level of recycling.

The results from the analysis of selected items in the instrument used to assess eleventh graders in Korea are summarized in Table 6 (p. 12). Of 24 items in the Knowledge scale, five were directly related to climate literacy. The percent of student who answered these five items correctly ranged from 30.8% to 75.9% (i.e., from low to moderate). The percent correct for three of these five items was greater than the percent correct for the entire 24-item scale (58.8%), although a relevant item for which this was not true pertained to the greenhouse effect. For the Affective scale and Behavior scale, each scale mean was transformed into an *overall item mean*. Of 27 Affective items, six were directly related to climate literacy. The mean score on only one of these six items was greater than for this overall item mean (M = 2.63; below "agree"), suggesting their dispositions were much more moderate. The only exception to this was the item pertaining to their willingness to walk instead of using in a car, which is consistent with third and seventh grade results on a comparable item. Of 28 items in the Behavior scale, six were directly related to climate literacy. The mean score on four of these six items was greater than the overall item mean (M = 2.22; slightly above "rarely"). As was found in prior samples, the eleventh graders' responses indicated their level of energy conservation was greater than their level of recycling.

Table 6. Results for Selected Items from the 11th Grade Assessment in Korea, by Component

Components	Items	% Correct or Mean
Knowledge	Total, Knowledge Scale (24 items)	58.8
	K7. Effect of environmental change in a pond food chain	70.9
	K8. Energy flow in the environment	30.8
	K14. Solar energy for producers	73.6
	K22. Contributors to the greenhouse effect	53.7
	K23. Source of oxygen in the atmosphere	75.9
Affective Dispositions	Total, Affective Scale (27 items)[1]	50.16 (2.63)[2]
	A5. Recycle aluminum cans (A)	2.47
	A16. Walk short distance instead of taking car (W)	3.11
	A17. Wear warm underclothes in winter to save energy (W)	2.27
	A24. Regulations of air pollution that obstruct industrial growth and development (A)[3]	1.85
	A25. Leave the lights on in an empty classroom (R)[3]	2.21
	A26. Drive a big family car (A)[3]	2.13
Behavior	Total, Behavior Scale (28 items)	49.10 (2.22)[4]
	B3. Walk, take public transportations, or ride bike instead of using a car	2.85
	B5. Put aluminum cans on the ground into recycle bin	2.11
	B7. Collect cups, containers, or bags for reusing later	2.11
	B9. Use both sides of paper when drawing or writing	2.99
	B11. Turn off the lights when leave a room	3.27
	B12. Purchase recycle/reusable products	2.26

[1] A: Environmental Attitude, W: Willingness, R: Personal Responsibility
[2] Mean scores fall along a 4-point scale: 1=strongly disagree; 2=disagree; 3=agree; and 4=strongly agree. Standard scores ranged from 0 - 100.
[3] The responses were reverse scored.
[4] Mean scores fall along a 4-point scale: 1=never; 2=rarely; 3=sometimes; and 4=always. Standard scores ranged from 0 - 100.

When these results from third, seventh, and eleventh grade Korean assessments were compared, the third graders exhibited more positive dispositions and a greater tendency to act responsibly than did the seventh and the eleventh graders (i.e., in that order). At the same time, the mean scores on the Knowledge scale all fell within 2.5 points of 60%. While the seventh grader mean was the highest of the three, difference in the number, content, and difficulty of items across the three instruments made it difficult, if not impossible, to undertake a similar comparison.

Climate literacy results from the national assessment in Israel, by grade level. The results of the analysis of selected items used to assess sixth graders in Israel are summarized in

Table 7, below. Of 19 items in the Knowledge scale, eight were directly related to climate literacy. The percent of students who answered these eight items correctly ranged from 23% to 70.5% (i.e., from low to moderate). The percent correct for four of these eight items was greater than the percent correct for the 19-item Knowledge scale (49.2%). These results indicated that the sixth graders were more knowledgeable about recycling, solar energy, ozone depletion, and air pollution than about global warming. For the Affective scale and the Behavior scales, each scale mean was transformed into an *overall item mean*. Of 18 Affective items, four were directly related to climate literacy. The mean score on three of these four items was equal to or greater than for this overall item mean (M = 4.53; slightly below "true"), pointing to relatively strong attitudes toward air/water pollution and recycling, although attitudes toward reducing petroleum consumption were not as strong (slightly below "fairly true"). Of eight items in the Behavior scale, two were directly related to climate literacy. The mean score on one of these items was

Table 7. Results for Selected Items from the 6th Grade Assessment in Israel, by Component

Components	Items	% Correct or Mean
Knowledge	Total, Knowledge Scale (19 items)	49.2
	53. Source of energy for life on the planet	28.4
	54. Main cause of global warming	29.0
	57. Effects of the holes in the stratospheric ozone	57.5
	59. Environmental advantages of a solar water heater	60.4
	60. Identifying recycle symbols	70.5
	62. Management of domestic garbage	23.3
	65. Effect of transportations on the environment	23.0
	68. Effect of air pollution	53.2
Affective Dispositions	Total, Attitude Scale (18 items)	81.49 (4.53)[1]
	36. No need to reduce petroleum consumption	3.75
	37. Produce electricity in less polluting ways even if it costs more	4.53
	43. Worry about the effect of air/water pollution on my and my family's health	4.98
	45. Recycling batteries, bottles and cans will improve environmental quality	4.65
Behavior	Total, Behavior Scale (8 items)	21.65 (2.71)[2]
	19. Turn off lights, lower the air conditioner or heater	3.41
	21. Recycle batteries, cans, bottles, paper, and newspapers	2.36

[1] Mean scores fall along a 6-point scale: 1=not true at all; 2=not true; 3=not so true; 4=fairly true; 5=true; and 6=very true. Raw scores ranged from 18 - 108.

[2] Mean scores fall along a 5-point scale: 1=never; 2=rarely; 3=sometimes; 4=often; and 5=always. Raw scores ranged from 8-40.

greater than the overall item mean (M = 2.71; between "rarely" and "sometimes"). Sixth graders' responses indicated their level of energy conservation was greater than their level of recycling.

The results of the analysis of selected items used to assess twelfth graders in Israel are summarized in Table 8, below. Of 17 items in the Knowledge test, nine were directly related to climate literacy. The percent of students who answered these nine items correctly ranged from 40.4% to 88.7% (i.e., from low to high). The percent correct for four of these nine items was greater than the percent correct for the 17-item Knowledge scale (61.4%). These results indicated that the twelfth graders, like the sixth graders, were more knowledgeable about recycling, ozone depletion, and air pollution than about global warming. For the Affective scale and the Behavior scales, each scale mean was transformed into an *overall item mean*. Of 27 Affective items, three were directly related to climate literacy. The mean score on two of these items was greater than

Table 8. Results for Selected Items from the 12th Grade Assessment in Israel, by Component

Components	Items	% Correct or Mean
Knowledge	Total (17 items)	61.4
	70. Identifying recycle symbols	88.7
	71. Effect of the holes in the stratospheric ozone	80.6
	73. Management of domestic garbage	60.8
	76. Main cause of global warming	40.4
	77. Effect of transportations on the environment	50.5
	79. Source of oxygen in the water	40.6
	80. Effect of sun on the earth	63.1
	83. Trend of electricity production in Israel	58.8
	84. Effect of air pollution	64.5
Affective Dispositions	Total, Attitudes (27 items)	108.9 (4.03)[1]
	43. Prefer public transportations over cars to reduce air pollution	2.43
	47. Worry about the effect of air/water pollution on the health of people in Israel	4.74
	59. Industry should be forced to reduce polluting emissions, even if it raises the price of products	4.31
Behavior	Total (12 items)	20.34 (1.70)[2]
	21 Turn off lights, lower the air conditioner or heater	3.39
	23. Recycle batteries, cans, bottles, paper, and newspapers	1.96

[1] Mean scores fall along a 6-point scale: 1=not true at all; 2=not true; 3=not so true; 4=fairly true; 5=true; and 6=very true. Raw scores ranged from 17 - 102.

[2] Mean scores fall along a 5-point scale: 1=never; 2=rarely; 3=sometimes; 4=often; and 5=always. Raw scores ranged from 12 - 60.

for this overall item mean (M = 4.03; slightly above "fairly true"), pointing to moderately strong attitudes toward causes, effects, and reduction of air/water pollution. Of 12 items in the Behavior scale, two were directly related to climate literacy. The mean score on both items was greater than the overall item mean (M = 1.7; below "rarely"). As with sixth graders, twelfth graders' responses indicated their level of energy conservation was greater than their level of recycling.

When these results from the sixth and twelfth grade Israeli assessments were compared, the sixth graders exhibited slightly stronger attitudes toward and a greater tendency to act responsibly than did the twelfth graders. While both samples tended to be more active in energy conservation than in recycling, as a whole, neither sample would be considered "active." At the same time, the mean scores on the Knowledge scale clearly indicated that twelfth graders were more knowledge than sixth graders about features of climate literacy. In both samples, students tended to be more knowledgeable about ozone depletion and air pollution than about global warming.

Climate literacy results from the national assessment in the U.S., by grade level. The results of the analysis of selected items in the instrument used to assess sixth and eighth graders in the U.S. are summarized in Table 9 (p. 16). Of 17 items in the Knowledge test, only two were directly related to climate literacy. The percentage of sixth graders who answered these two items correctly ranged from 56% to 79%, and of eighth graders who did so ranged from 63% to 80% (i.e.. moderate for both grades). The percent correct for one of these two items was greater than the percent correct for the 22-item Knowledge scale (6th: 66.1% and 8th: 68.4%). These results indicated that sixth and eighth graders were reasonably knowledgeable about the source of oxygen in the Earth's atmosphere, but less so about the source of energy for most living things.

For the Affective scale and the Behavior scale, each scale mean was transformed into an *overall item mean*. Of 12 items in the Willingness scale, five were directly related to climate literacy. Among sixth graders, the mean score on three of these five items was greater than for this overall item mean (M = 3.67; below "mostly true"), while among eight graders, the mean score on four of these five items was greater than for the overall item mean (M=3.43; between "mostly true" and "not sure"). For both sixth and eighth graders, their willingness to recycle was highest, followed by using dimmer light bulbs and persuading others to recycle. Students in each grade

Table 9. Results for Selected Items from the 6th and 8th Grade Assessment in the U.S., by Component

Components	Items	% Correct or Mean	
		6th	8th
Knowledge	Total (17 items)	66.1	68.4
	14. Energy source for most living things	56.0	63.0
	17. Source of oxygen in the atmosphere	79.0	80.0
Affective Dispositions	Total, Willingness (12 items)	43.89 (3.67)[1]	41.10 (3.43)[1]
	23. Save energy by using less AC[2]	3.42	3.22
	26. Walk places to reduce air pollution	3.62	3.46
	27. Separate family trash for recycling[2]	3.74	3.55
	29. Use dimmer light bulbs to save energy	3.70	3.53
	33. Ask people who don't to recycle	3.70	3.44
Behavior	Total (12 items)	38.44 (3.20)[1]	35.14 (2.93)[1]
	37. To save energy, turn off lights	3.96	3.74
	39. Persuade family members to recycle	3.48	3.16
	43. Close refrigerator door while deciding	3.15	2.81
	45. Separate things for home recycling[2]	3.43	3.29

[1] Mean scores fall along a 5-point scale: 1=very false; 2=mostly false; 3=not sure; 4=mostly true; and, 5=very true. Raw scores ranged from 12 - 60.
[2] The responses were reverse scored.

were less willing to conserve energy by using less air conditioning. Of 12 items in the Behavior scale, four were directly related to climate literacy. The mean score on three of these four items was greater than the overall item mean for sixth graders (M=3.2; slightly above "not sure") and for eighth graders (M=2.93; slightly below "not sure"). These results indicated that sixth and eighth grades tended to turn off light to conserve energy most often (slightly below "mostly true") and close the refrigerator door when making decisions much less often (slightly above and below "not sure", respectively). Both sixth and eighth graders' tendency to recycle and persuade others to recycle fell between these two energy conservation behaviors.

When the results from the sixth and eighth grade U.S. assessment were compared, the sixth graders exhibited a greater willingness to and a greater tendency to act responsibly than did the eighth graders. At the same time, the mean scores on the Knowledge scale for sixth and eighth graders all fell within 2.3 points of each other, with eighth graders exhibiting slightly greater knowledge These patterns are consistent with patterns within the data sets for national baseline

sample of sixth and eight graders (McBeth et al., 2008), and with patterns in the data set for the subsequent study involving sixth, seventh, and eighth grade students exposed to environmental education programming (McBeth et al., 2011). .

Climate literacy results from the national assessment in Turkey. The results from the analysis of selected items in the instrument used to assess fifth graders (10-11 year olds) in Turkey are summarized in Table 10 (p. 18). Of 22 items in the Knowledge scale, eight were directly related to climate literacy. The percentage of students who answered these eight items correctly ranged 56.2% to 89.4% (i.e., from medium to high). The percent correct for five of these eight items was greater than the percent correct for the 22-item Knowledge scale (70.7%). These results indicated that fifth graders were more knowledgeable about layers of the earth, forms of water, and fossils fuels, and less so about wind energy and energy consumed by home appliances.

For the Affective scale and the Behavior scales, each scale mean was transformed into an *overall item mean*. Of 14 Affective items, only two were directly related to climate literacy. The item mean for one of these items was slightly higher than this scale's overall item mean (M = 3.42; between "agree" and "strongly agree"), indicating a strong willingness to take action to prevent environmental problems. The mean score for the other item was nearly as high ("agree") indicating a relatively strong inclination to change their lifestyle to help protecting natural resources. Of the 23 items related to Behavior, five items were directly related to climate literacy. The mean score on all five of these items was greater than the overall item mean (M = 3.18; or more than "three times in the last year"). These results indicated that students tended to be moderately actively involved in conserving water, persuading others to conserve water and electricity, and slightly less so in reusing, recycling, and purchase recycled/recyclable goods.

Results for Question 2: Comparison of climate literacy results from these national assessments across grade levels. As indicated in Table 3 (p. 7), the results from these four national assessments were organized into three grade levels for reporting and comparison purposes: elementary; middle; and secondary. Within each level, patterns were noted among

Table 10. Results for Selected Items from the 5th Grade Assessment in Turkey, by Component

Components	Items	% Correct or Mean
Knowledge	Total (22 items)	70.7
	K4. Coal and petroleum are examples of …	84.6
	K5. Source of energy in food chains on land	79.8
	K6. Reasons of breaking the balance of environment	61.5
	K12. Identifying non-recyclable material	82.0
	K14. Energy consumption of home appliances	46.5
	K16. Layers of the earth	89.4
	K20. Different forms of water	88.2
	K21. Energy produced from wind as a clean source of energy	56.2
Affective Dispositions	Total (14 items)[1]	47.83 (3.42)[2]
	A11. I can change my lifestyle to protect natural resources (A)	3.03
	A12. I am willing to take actions to prevent environmental problems (e.g., recycle, not littering, etc) (W)	3.46
Behavior	Total (23 items)	73.17 (3.18)[3]
	B9. Separate paper, glass, plastic, cans, aluminum, and batteries into recycling bin	3.43
	B12. Take steps to save water	5.04
	B13. Purchase products that are recyclable or made from recycled materials	3.51
	B16. Ask people not to use water and electricity if not necessary	4.40
	B17. Donate items that are not used to people and institutions in need	4.08

[1] A: Environmental Attitude, W: Willingness

[2] Mean scores fall along a 4-point scale: 1=strongly disagree; 2=disagree; 3=agree; and 4=strongly agree. Total scores ranged from Raw scores ranges from 14 - 56.

[3] Mean scores fall along a 7-point scale: 0=never; 1=1x in the last year; 2=2x in the last year; 3= 3x in the last year; 4=4x in the last year; 5=5x in the last year; 6= more than 5x in the last year. Raw scores range from 0 -114.

selected items associated with the knowledge, affective dispositions, and behavioral components of environmental literacy. In those cases where items were similar in content, comparisons between samples within each grade level were made. However, due to the small number of items to support such comparisons, more general comparisons also were made in an effort to detect and portray any patterns within these results for that grade level. The results of these comparisons are summarized below.

Comparison of climate literacy results for elementary-level samples. The first set of comparisons focused on results for the two elementary-level samples: the third-grade sample from Korea, and the fifth-grade sample from Turkey. The scale used to assess the *knowledge* of third graders from Korea consisted of 24 items (% Correct = 61.8%), five of which were directly related to climate literacy (range of percent correct = 39.6% to 97%) (Table 4, p. 9), and the scale used with fifth graders in Turkey consisted of 22 items (% Correct = 70.7%), eight of which were directly related to climate literacy (range of percent correct = 46.5% to 89.4%) (Table 10, p. 18). Two items in each knowledge scale were similar enough in content to permit more specific comparisons. One of these pair of items pertained to ecology, and focused on the primary energy source for living things. For this pair, the fifth-grade sample from Turkey (79.8%) appeared to be more knowledgeable than the third-grade sample from Korea (39.6%). The second pair of items pertained to environmental science, and focused on materials that were not recyclable. On these items, the fifth-grade sample from Turkey (82%) also was more knowledgeable than the third-grade sample from Korea (72.2%), but the apparent difference in knowledge was much smaller in magnitude. While these results appear to suggest that fifth graders from Turkey tended to be more knowledgeable, difference in the content of the other 20-some-odd items and in item difficulty limit this comparison from both a technical and practical perspective. In summary:

a) the overall level of environmental knowledge in these two elementary samples tended to be moderate;
b) the samples' knowledge on items pertaining to climate literacy tended to fluctuate from low or moderate to high, depending on the content assessed; and
c) given the constrains upon item comparisons, the fifth grade sample from Turkey appeared to be more knowledgeable than the third grade sample from Korea.

The scale used to assess the *affective dispositions* of third graders from Korea consisted of 22 items (Overall Item Mean = 3.06 on 4-pt. scale), five of which were directly related to climate literacy (range of item means = 2.96 to 3.59), and the scale used with fifth graders in Turkey consisted of 14 items (Overall Item Mean = 3.42 on a 4-pt. scale), two of which were directly related to climate literacy (range of item means = 3.03 to 3.46). While the selected items in each scale included attitudinal and willingness (intention) items, the differences in the wording of these items made meaningful comparisons almost impossible. The two selected items in the scale used with fifth graders in Turkey were worded very generally (i.e., protecting natural resources

and preventing environmental problems), while the five selected items in the scale used with third graders in Korea tended to be more issue-specific. The only general comparison that could be made was between an attitudinal item in the Korean scale (A8) and a willingness item in the Turkish scale (A12), as both pertain, at least in part, to pollution prevention. The results on this Korean (M = 3.59 on a 4-pt. scale) and this Turkish item (M = 3.46 on a 4-pt. scale) indicated strong, positive dispositions in both samples. In summary:

a) the overall strength of environmental dispositions in these two elementary samples tended to be positive, with the sample from Turkey evidencing a higher overall item mean;
b) the samples' dispositions pertaining to climate change tended to be positive (i.e., approaching or above "agree"); and
c) given the constraints upon item comparisons, there appeared to be little, if any, difference in the climate change-related dispositions of these two samples.

The scale used to assess participation in *responsible environmental behavior* by third graders from Korea consisted of 16 items (Overall Item Mean = 2.79 on a scale of 1-4), five of which were directly related to climate literacy (range of item means = 2.77 to 3.35), and the scale used with fifth graders in Turkey consisted of 23 items (Overall Item Mean = 3.18 on a scale of 0-6), five of which were directly related to climate literacy (range of item means = 3.43 to 5.04). Several items in each behavior scale were similar enough in content to permit more specific comparisons, although the measurement scales used in these two assessments differed in kind (i.e., ordinal vs. ratio) and in the range of values, seriously limiting meaningful comparisons (see Note 4 beneath Table 4, p. 9, and Note 3 beneath Table 10, p. 18). One of these pair of items pertained to recycling. For this pair, the third-grade sample from Korea (M = 2.84 out of 4, which was slightly below "sometimes") appeared to be about as active as the fifth-grade sample from Turkey (M = 3.43 out of 6, which fell between 3-4 times in the last year). The second pair of items pertained to taking steps not to waste energy, although the item in the Korean assessment was more specific. For this pair of items, the third-grade sample from Korea (M = 3.35 out of 4, which was above "sometimes") again appeared to be about as active as the fifth-grade sample from Turkey (M = 4.40 out of 6, which was between 4-5 times in the last year). In summary:

a) the overall frequency of developmentally appropriate responsible environmental behaviors in these two elementary samples tended to be moderate, falling slightly below "sometimes" for the third-grade sample from Korea, and slightly above three times in the last year for the fifth-grade sample from Turkey;
b) the samples' level of behavior on items pertaining to climate change tended to be slightly to moderately above that for the overall behavior scale; and
c) given the constraints upon item comparisons, there appeared to be little, if any, difference in the climate change-related behavior of these two samples.

Comparison of climate literacy results for middle-level samples. The second set of comparisons focused on results for the three middle-level samples: the sixth-grade sample from Israel, the seventh-grade sample from Korea, and the sixth- and eighth-grade sample from the U.S. The scale used to assess the *knowledge* of students in each of these samples was a follows:

- the scale used with sixth graders in Israel consisted of 19 items (% Correct = 49.2%), eight of which were directly related to climate literacy (range of percent correct = 23% to 75%) (Table 7, p. 13);
- the scale used with seventh graders in Korea consisted of 27 items (% Correct = 62.4%), ten of which were directly related to climate literacy (range of percent correct = 21.7% to 75%) (Table 5, p. 10); and
- the scale used with sixth and eighth graders in the U.S. consisted of 17 item (6th grade % Correct = 66.1%; 8th grade % Correct = 68.4%), two of which were directly related to climate literacy (6th grade range of percent correct = 56% to 79%; 8th grade range of percent correct = 63% to 80%) (Table 9, p. 16).

Of the items that were directly related to climate literacy, comparisons were made on four sets of items. The first sets of items pertained to ecology, and focused on the primary energy source for living things. For these items, the eighth- and sixth-grade samples from the U.S. (63% and 56%, respectively) appeared to be more knowledgeable than the seventh-grade sample from Korea (48.6%) and the sixth-grade sample from Israel (28.4%). The second of items sets focused on the source of oxygen in the atmosphere. For this set, the eighth- and sixth-grade samples from the U.S. (80% and 79%, respectively) appeared to be more knowledgeable than the seventh-grade sample from Korea (65.3%). The third set of items focused on the cause of global warming. For this set, the seventh-grade sample from Korea (53.3%) appeared to be more knowledgeable than the sixth-grade sample from Israel (29%). The fourth set of items pertained to ozone depletion, although the item presented the seventh-grade sample from Korea focused on causes (75%),

while the item presented to the sixth-grade sample from Israel focused on effects (57.5%). In summary:

a) the overall level of environmental knowledge in these three middle-level samples tended to be moderate;
b) the samples' knowledge on items pertaining to climate literacy tended to fluctuate from low to high, depending on the content assessed; and
c) given the constrains apparent in items comparisons, the eighth- and sixth-grade samples from the U.S. appeared to be more knowledgeable on items assessing basic science concepts, while the seventh-grade sample from Korea appeared to be more knowledgeable than the sixth-grade sample from Israel on relevant global warming and ozone depletion items.

The scale used to assess the *affective dispositions* in each of these samples was a follows:

- the scale used with sixth graders in Israel consisted of 18 items (overall item mean = 4.53 on a 6-pt. scale, which fell between "fairly true" and "true", and which converted to 75%). Four of these 18 items were directly related to climate literacy (range of item means = 3.75 to 4.98);
- the scale used with seventh graders in Korea consisted of 27 items (overall item mean = 2.83 on a 4-pt. scale, which fell slightly below "agree", and which converted to 70.75%). Six of these 27 items were directly related to climate literacy (range of item means = 2.51 to 3.12); and
- the scale used with sixth and eighth graders in the U.S. consisted of 12 items The sixth grade overall item mean was 3.67 on a 5-pt. scale, which fell between "not sure" and "mostly true", and which converted to 73.4%. The eighth grade overall item mean was 3.43 on this same scale, which also fell between "not sure" and "mostly true", and which converted to 68.6%. Five of these 12 items were directly related to climate literacy (6th grade range of item means = 3.42 to 3.74; 8th grade range of item means = 3.22 to 3.55).

There were several noteworthy differences among the items in these scales that complicated and/or limited the extent to which items could be compared. First, the affective disposition(s) that were assessed differed: there were *attitude* items in the scale used in Israel (Table 7, p. 13), *willingness* items in the scale used in the U.S. (Table 9, p. 16), and a mix of *attitude*, *responsibility*, and *willingness* items in the scale used in Korea (Table 5, p. 10). Second, as noted above, there were differences in scale values and in the number of points in each measurement scale, although the latter may be addressed by transforming item mean scores into percentages. Third, the subject matter in the selected items varied, thereby providing different referents (stimuli) to which students were asked to respond. As a result, only one set of items seemed to be

comparable, and those were the items pertaining to recycling. The results for the items focused on *disposition towards recycling* were as follows:

- for the sixth-grade sample in Israel, the item mean (4.65 on a 6-pt. scale) converted to 77.5%;
- for the seventh-grade sample in Korea, the item mean (2.64 on a 4-pt. scale) converted to 66%; and
- for the sixth- and eighth-grade samples in the U.S., the item means (6th: 3.74 and 8th: 3.55, on a 5-pt. scale) converted to 74.8% and 71%, respectively.

In summary, (a) the environmental dispositions in these middle-level samples tended to be moderately positive. Using converted values for overall item means, slightly more positive dispositions were apparent in the sixth-grade samples from Israel (75%) and the U.S. (73.4%), followed by the seventh-grade sample from Korea (70.75%), and then eighth-grade sample from the U.S. (68.6%). Further, (b) the samples' dispositions pertaining to climate change tended to be positive (i.e., approaching or above "mostly true", "true", or "agree"). Finally, (c) in light of numerous differences in what was assessed and how this was done, the comparison of results across samples was extremely limited. For the one comparison that was made, the results appeared to be generally consistent with those noted in (a) for the entire affective dispositions scales.

The scale used to assess participation in *responsible environmental behavior* in each of these samples was a follows:

- the scale used with sixth graders in Israel consisted of 8 items (overall item mean = 2.71 on a 5-pt. scale, which fell between "rarely" and "sometimes" and which converted to 54.2%), two of which were directly related to climate literacy (range of item means = 2.36 to 3.41);
- the scale used with seventh graders in Korea consisted of 25 items (overall item mean = 2.42 on a 4-pt. scale, which fell between "rarely" and "sometimes" and which converted to 60.5%), five of which were directly related to climate literacy (range of item means = 2.32 to 3.44); and
- the scale used with sixth and eighth graders in the U.S. consisted of 12 items The sixth grade overall item mean was 3.20 on a 5-pt. scale, which fell between "not sure" and "mostly true", and which converted to 64%. The eighth grade overall item mean was 2.93 on this same scale, which also fell slightly below "not sure", and which converted to

58.6%. Of these 12 items, four were directly related to climate literacy (6th grade range of item means = 3.15 to 3.96; 8th grade range of means = 2.81 to 3.74).

As is apparent above, a number of the differences in the scales used to assess affective dispositions in these national assessments also were apparent in the scales used to assess responsible environmental behavior (i.e., differences in target issues and associated behavior, in the phrasing of items, in the phrasing for scale values, and in the number of points in each scale). Nonetheless, two items in these behavior scales were similar enough in content to permit comparison. The first of these items pertained to energy conservation. The results on the set of items pertaining to turning off lights to conserve energy indicated that all middle-level samples tended to do this:

- for the sixth-grade sample from Israel, the item mean = 3.41 on a 5-pt. scale, which fell between "sometimes" and "frequently";
- for the seventh-grade sample from Korea, the item mean = 3.44 on a 4-pt. scale, which also fell between "sometimes" and "frequently"; and
- for the sixth- and eighth-grade samples from the U.S., the item means were 3.96 and 3.71, respectively, both of which fell slightly below "mostly true."

The results for items pertaining to recycling indicated that students across samples were more prone to turn off lights than to recycle. However, the results on the recycling items were more difficult to compare due to differences in scale values:

- for the sixth-grade sample from Israel, the item mean = 2.36 on a 5-point scale, which fell between "rarely" and "sometimes";
- for the seventh-grade sample from Korea, the item mean = 2.32 on a 4-pt. scale, which also fell between "rarely" and "sometimes"; and
- for the sixth- and eighth-grade sample from the U.S. , the 6th grade item mean = 3.43, and 8th grade item mean = 3.29, both on a 5-pt. scale, and both of which fell between "not sure" and "mostly true".

In summary, (a) the mean score on the responsible environmental behavior scale used in each of these three national assessments indicated that these middle-level samples tended to be active "sometimes", although scores on the behavior scale were slightly to noticeably lower than on the associated dispositions scale. Further, (b) these samples' behavior on items related to climate change tended to vary from "rarely" to greater than "sometimes". Finally, (c) the comparison of

results across these samples on similar items indicated that middle-level students in all three nations were more prone to turn off lights to conserve energy than to recycle. The gap between these was more apparent in the samples from Israel and Korea than in the samples from the U.S.

Comparison of climate literacy results for secondary-level samples. The third and final set of comparisons focused on results for the two secondary-level samples: the 11th-grade sample from Korea, and the 12th-grade sample from Israel. The scale used to assess the *knowledge* of eleventh graders from Korea consisted of 24 items (% Correct = 58.8%), five of which were directly related to climate literacy (range of percent correct = 30.8% to 75.9%) (Table 6, p. 12), and the scale used with twelfth graders in Israel consisted of 17 items (% Correct = 61.4%), nine of which were directly related to climate literacy (range of item percent correct = 40.4% to 88.7%) (Table 8, p. 14). The only items in each knowledge scale that were similar enough in content to permit comparisons pertained to causes of the greenhouse effect (global warming). For this pair of items, the eleventh-grade sample from Korea (53.7%) appeared to be more knowledgeable than the twelfth-grade sample from Israel (40.4%). However, these item means indicated that, as a whole, students in each national sample evidenced limited knowledge on items in this area. In summary:

a) the overall level of environmental knowledge in these two secondary samples tended to be moderate;
b) the samples' knowledge on items pertaining to climate literacy tended to fluctuate from low to high, depending on the subject matter assessed; and
c) on the one pair of items on which a comparison could be made (causes of global warming), the eleventh-grade sample from Korea scored higher than the twelfth-grade sample from Israel, although the level of knowledge about this in both samples was limited.

The scale used to assess the *affective dispositions* of eleventh graders from Korea consisted of 27 items (Overall Item Mean = 2.63 on 4-pt. scale), six of which were directly related to climate literacy (range of item means = 1.85 to 3.11), and the scale used with twelfth graders in Israel also consisted of 27 items (Overall Item Mean = 4.03 on a 6-pt. scale), three of which were directly related to climate literacy (range of item means = 2.43 to 4.74). As in prior grade-level comparisons, differences in the dispositions assessed (Israel: *attitudes* only, Korea: *attitudes*, *responsibility*, and *willingness*), in the response scale (Israel: 6 pt. and Korea: 4 pt.), in content

that served as referents, and in the wording of these items made meaningful comparisons difficult. With these difficulties in mind, general comparisons were made on two pairs of items. The first general comparison was between a willingness item in the Korean scale (A16) and an attitudinal item in the Israeli scale (43), as both pertained to a preference for a mode of transportation that would be less polluting than cars (i.e., Korea: walking, Israel: public transportation). The results on this Korean item (M = 3.11 on a 4-pt. scale, which was above "agree") and this Israeli item (M = 2.43 on a 6-pt. scale, which fell between "not true" and "not so true") were quite different. The eleventh-grade sample from Korea exhibited a much more positive disposition, although it must be recognized that part of the difference in these results could be attributed to the difference between "walking" and "public transportation". The second general comparison was between an attitudinal item in each scale (Korean: A24, Israel: 59) that pertained to the regulation of polluting industries, presumably by governmental agencies. The results on this Korean item (M = 1.85 on a 4-pt. scale, which fell below "disagree) and this Israeli item (M = 4.31 on a 6-pt. scale, which was above "fairly true") were noticeably different. While some of this difference also could be attributed to differences in item wording, it appeared as if the students in the twelfth-grade sample from Israel were more in favor of regulating polluting industries than were students in the eleventh-grade sample from Korea. In summary:

a) the overall strength of environmental dispositions in these two secondary samples tended to be mixed or slightly positive, with the sample from Korea evidencing an overall item mean (M = 2.46 on a 4-pt. scale, which fell between "disagree" and "agree") and the sample from Israel (M = 4.03 on a 6-pt. scale, which was slightly above "fairly true");
b) the samples' dispositions on items pertaining to climate change tended to be vary considerably, depending upon the subject matter or referent (sample from Korea: from below "disagree" to above "agree"; sample from Israel: from below "not so true" to slightly above "true"); and
c) given the constraints upon item comparisons, there were noticeable differences in the results in both comparisons that were made. The sample from Korea appeared to show a stronger preference for a less polluting mode of transportation than cars, while the sample from Israel appeared to show a stronger preference for regulation of polluting industries. The former appeared focus more on dispositions associated with personal behavior, while the latter on dispositions associated with government intervention.

The scale used to assess participation in *responsible environmental behavior* by eleventh graders from Korea consisted of 28 items (Overall Item Mean = 2.22 on a 4-pt. scale), six of which were directly related to climate literacy (range of item means = 2.11 to 3.27), and the scale used with

twelfth graders in Israel consisted of 12 items (Overall Item Mean = 1.70 on a 5-pt. scale), two of which were directly related to climate literacy (range of item means = 1.96 to 3.39). As in the comparison of scales and items used to assess affective disposition, differences in the response scale (Israel: 5 pt., Korea: 4 pt.), in content that served as referents, and in the wording of these items made meaningful comparisons difficult. With these difficulties in mind, general comparisons were made on two pairs of items. The first pairs of items pertained to students turning off lights (and other utilities) to conserve energy (Korea: B11, Israel: 21). The results on this Korean item (M = 3.27 on a 4-pt. scale, which was above "sometimes") and on this Israeli item (M = 3.39 on a 5-pt. scale, which was above "sometimes") were consistent, suggesting a moderate level of energy conservation in both samples. The second pair of items pertained to students engaging in recycling (Korea: B5 and Israel: 23). The results on this Korean item (M = 2.11 on a 4-pt. scale, which was slightly above "rarely") and this Israeli item (M = 1.96 on a 5-pt. scale, was slightly below "rarely") also were consistent, suggesting a relatively low level of participation in recycling in both samples. In summary:

a) the overall frequency of developmentally appropriate responsible environmental behaviors in these two secondary samples tended to be relatively low, falling slightly above "rarely" for the eleventh-grade sample from Korea, and slightly below "rarely" for the twelfth-grade sample from Israel;
b) the samples' level of behavior on items pertaining to climate change tended to vary from slightly below or above "rarely" (low) to above "sometimes" (moderate), depending on the specific behavior(s) assessed; and
c) despite differences in the item content and measurement scales used in each assessment, students in both samples tended to engage in energy conservation at a moderate level, although more frequently than in recycling.

Results for Question 3: Comparison of results on selected items across national assessments and grades, by major environmental literacy component. In the section on *Results for Question 1*, some general comparisons were made across samples within each national assessment on students' knowledge, affective dispositions, and behaviors associated with environmental literacy. In the section on *Results for Question 2*, some general comparisons were made across samples within each grade level on students' knowledge, affective dispositions, and behaviors associated with environmental literacy, and a limited number of

comparisons were made across these samples on knowledge, affective disposition, and behavior items directly related to climate literacy. In the case of the former, comparisons were made *across grades within each national assessment*, while in the latter comparisons were made *across national assessments represented within each grade level*. In this section, the results of item-specific comparisons *across both national assessments and grades* will be reviewed and summarized. Separate summaries will be presented for items that assessed knowledge, affective dispositions, and behavior directly related to climate literacy.

Comparison of results on selected knowledge items across national assessments and grades. Due to the fact that this comparison focuses on climate change, team members chose to organize and summarize results for selected knowledge items in two specific areas and in two general areas. These two specific areas were: (a) knowledge of global warming; and (b) knowledge of ozone depletion, due to its role in the climate systems and to the common tendency for students to confuse aspects of ozone depletion with aspects of global warming (e.g., Boyes, 2011). These two general areas were: (c) knowledge of Earth and ecological systems, which may be viewed as foundational or prerequisite to students' knowledge of climate change (e.g., Hungerford, Peyton, & Wilke, 1980; U.S. Global Change Research Program/Climate Change Science Program, 2009); and (d) knowledge in the environmental sciences, including knowledge of problems and solutions that are related to climate change (e.g., Hungerford, Peyton, & Wilke, 1980; U.S. Global Change Research Program/Climate Change Science Program, 2009).

The results for selected knowledge items in these four areas are summarized in Table 11 (p. 29). First, four items within these national assessments were used to assess (a) students' knowledge of global warming: two in the Korean assessment (7th and 11th grades); and two in the Israeli assessment (6th and 12th grade). The percent correct on these items suggest a low-to-moderate level of knowledge in the samples from Korea (7th: 53.3%, 11th: 53.7%), and a lower level of knowledge in the samples from Israel (6th: 29%, 12th: 40.4%). Within both of these national assessments, students in the upper grade outscored students in the lower grade, although the difference in mean scores for the two samples from Korea is negligible. Second, three items in these national assessments were used to assess (b) students' knowledge of ozone depletion: one on causes in the Korean assessment (7th grade); and two on effects in the Israeli assessment

Table 11. Results for Selected Knowledge Items across National Assessments and Grades

National Assessment	Korea			Israel		U.S.		Turkey
Grades	3rd	7th	11th	6th	12th	6th	8th	5th
Areas of Knowledge	**Item # (% Correct)**							
A. Global warming	-	K17 (53.3)	K22 (53.7)	54 (29.0)	76 (40.4)	-	-	-
B. Ozone depletion	-	K18 (75.0)	-	57 (57.5)	71 (80.6)	-	-	-
C. Supporting earth/ ecological systems	K13 (39.6) K15 (97.0)	K5 (48.6) K7 (53.2) K8 (65.3) K9 (55.8)	K7 (70.9) K8 (30.8) K14 (73.6) K23 (75.9)	53 (28.4)	79 (40.6) 80 (63.1)	14 (56.0) 17 (79.0)	14 (63.0) 17 (80.0)	K5 (79.8) K16 (89.4) K20 (88.2)
D. Associated environmental sciences	K17 (52.4) K18 (72.2) K19 (95.1)	K22 (55.0) K24 (37.5) K25 (66.9) K27 (21.7)	-	59 (60.4) 60 (70.5) 62 (23.3) 65 (23.0) 68 (53.2)	70 (88.7) 73 (60.8) 77 (50.5) 83 (58.8) 84 (64.5)	-	-	K4 (84.6) K6 (61.5) K12 (82.0) K14 (46.5) K21 (56.2)

Table 12. Results for Selected Affective Disposition Items across National Assessments and Grades

National Assessment	Korea			Israel		U.S.		Turkey
Grades	3rd	7th	11th	6th	12th	6th	8th	5th
Affective Dispositions	**Item # (Mean)**[1]							
A. Alternative transportation	A16 (3.42)	A18 (3.12)	A16 (3.11)	-	43 (2.43)	26 (3.62)	26 (3.46)	-
B. Regulation of polluting industries	-	A10 (2.51)	A24 (1.85)	-	59 (4.31)	-	-	-
C. Conserve energy	A21 (2.96)	A19 (2.60) A25 (2.83)	A17 (2.27) A25 (2.21)	36 (3.75)	-	23 (3.42) 29 (3.70)	23 (3.22) 29 (3.53)	-
D. Reuse/recycle	A12 (3.13)	A5 (2.64)	A5 (2.47)	45 (4.65)	-	27 (3.74) 33 (3.70)	27 (3.55) 33 (3.44)	A12 (3.46)

[1] Mean scores fall along 4-point scale (Korea), 6-point scale (Israel), 5-point scale (U.S.), and 4-point scale (Turkey).

(6th and 12th grades). The percent correct on these items suggest a moderately high level of knowledge in the sample from Korea (75%), and a moderate to moderately high level of knowledge in these samples from Israel (6th: 57.5%, 12th: 80.6%). Within the Israeli national assessments, students in the upper grade outscored students in the lower grade. When the results for (b) items on ozone depletion were compared to results on (a) items on global warming, it was apparent that students' knowledge of ozone depletion was substantially greater than their knowledge of global warming (i.e., differences in the percent correct were 21.7 - 28.5% in the middle grades, and was 40.2% in the secondary grade).

As noted in Table 11 (p. 29), comparisons also were made in two general areas: (c) knowledge of Earth and ecological systems; and (d) knowledge of the environmental sciences. The number of items in each of these areas was greater than for (a) and (b). The items in (c) and (d) reflect diverse contents that make specific item-to-item comparisons difficult. However, when viewed as a whole, these items reflect evidence from a larger sample of items in each of these domains, allowing more general patterns in student knowledge to be discerned.

Several general patterns were apparent in the results pertaining to (c) students' knowledge of Earth and ecological systems. Within the Korean assessment, third graders' knowledge varied considerably (39.6% to 97%), while seventh graders' knowledge was less varied and more moderate (48.6% to 65.3%), and eleventh graders' knowledge was greater (70.9% to 75.9%), with the exception of item K8, which pertained to energy flow (30.8%). Within the Israeli assessment, the twelfth graders' knowledge on these items (40.6% to 63.1%) was greater than sixth graders' knowledge on this item (28.4%), although the small number of items renders this questionable and therefore tentative. Within the U.S. assessment, eighth graders outscored sixth graders on both of these items. Thus, with the exception of item K8 in the Korean assessment, the results on these items in these three national assessments are orderly, and reflect what one would anticipate on the basis of developmental factors and educational experiences. However, the results within the Turkish assessment vary from this pattern, with fifth graders' scoring relatively high on all three items (79.8% to 89.4%). The percent correct on these items are consistently higher than for any of the other samples. One possible explanation for this apparent discrepancy is that the items in this assessment were closely aligned to the Turkish national

curriculum for 4th and 5th grade (Erdogan & Ok, 2011, p. 9), and this was not apparent in any of the other three national assessments (McBeth et al., 2008; Negev et al., 2008; Shin et al., 2005).

Several general patterns also were found in the results pertaining to (d) students' knowledge of the environmental sciences. Within the Korean sample, items in this area appeared in the third grade and seventh grade assessments. There was considerable variability in the percent correct for third graders (52.4% to 95.1%) and for seventh graders (21.7% to 66.9%), and no apparent pattern when these results were compared across grades. Within the Israeli sample, there also was considerable variability in the percent correct for sixth grades (23% to 70.5%) and for twelfth graders (50.5% to 88.7%). However, as was found for items in (c), twelfth graders' knowledge appeared to be greater than sixth graders'. Lastly, within the Turkish assessment, the results indicate greater variation in students' knowledge (46.5% to 84.6%) than was apparent for items in (c). Inferences as to why the results for items in (c) would differ from results for items in (d) were not as readily apparent, although this could be due to differences in the level of curricular and instructional attention in schools in Turkey to content in each area. When these results were viewed across grade levels and national assessments, students' knowledge in (d) tended to vary from low to high, depending on the particular content (problem or solutions) featured in each of the selected items.

Comparison of results on selected affective disposition items across national assessments and grades. Due to the fact that this comparison focuses on climate change, team members chose to organize and summarize results for selected disposition items in two specific areas and in two general areas. These two specific areas were: (a) attitudes toward and willingness to use a mode of transportation that would be less polluting than cars (i.e., Korea and U.S.: walking; Israel: public transportation); and (b) attitudes toward the regulation of polluting industries, presumably by governmental agencies. These two general areas were: (c) attitudes toward and willingness to take other steps to conserve energy; and (d) attitudes toward and willingness to reuse, engage in recycling, and purchase recycled/recyclable goods, due to the impact of these activities on less immediate, but prominent reductions in energy consumption that would have been used to refine raw materials and manufacture goods.

The results for selected disposition items in these four areas are summarized in Table 12 (p. 29). First, three items within these national assessments were used to assess (a) students' dispositions towards a mode of transportation other than cars: the same item in each of the Korean assessments (3rd, 7th and 11th grade); one in the Israeli assessment (12th grade); and one in the U.S. assessment (6th and 8th grade).). Of these three items, two were willingness items that pertained to walking instead of using a car: the third-grade sample from Korea (M = 3.42 on a 4-pt. scale, which was between "agree" and "strongly agree"); the seventh-grade sample from Korea (M = 3.12 on a 4-pt. scale, which was slightly above "agree"); the eleventh-grade sample from Korea (M = 3.11 on a 4-pt. scale; which also was slightly above "agree"); the sixth-grade sample from the U.S. (M = 3.62 on a 5-pt. scale, which was between "not sure" and "mostly true"); and the eighth-grade sample from the U.S. (M = 3.46 on a 5-pt. scale, which also was between "not sure" and "mostly true"). Two patterns are apparent in these results. Within each national assessment, younger students scored higher than older students, although the reasons for this pattern are solely a matter of speculation (e.g., greater enthusiasm among younger students, greater knowledge and experience among older students). Further, across these two national assessments, the samples from Korea expressed a greater willingness to walk than did the samples from the U.S. The fifth and final item was an attitudinal item that pertained to the use of public transportation in place of cars in the Israeli assessment (M = 2.43 on a 6-pt. scale, which was between "not true" and "not so true"). While the results on this item are lower than for any of the items that pertained to walking, the difference in content (referent) limits this comparison (i.e., Korean and U.S. samples were not asked about their attitudes toward or willingness to use public transportation in place of cars).

Second, three items within these national assessments were used to assess (b) students' attitudes toward the regulation of pollution, either explicitly or implicitly by governmental agencies. One item in the seventh-grade Korean assessment pertained to the government's role in encouraging people to drive energy efficient cars (M = 2.51 on a 4-pt. scale, which was between "disagree" and "agree"). When compared to the results on the willingness item that pertained to walking instead of driving in cars, the results for this item were lower, which may suggest that these seventh graders' dispositions were more favorable toward matters of personal choice than toward government regulation when it came to cars. The results of the comparison of the other two items

were presented in the previous section (see p. 26), and indicated that students in the twelfth-grade sample from Israel were more in favor of regulating polluting industries than were students in the eleventh-grade sample from Korea.

Several general patterns were apparent in the results pertaining to (c) students' attitudes toward and willingness to take other steps to conserve energy. In all, five items were used to assess selected dispositions in this area. One of these items was a meaning-reversal (or negatively-worded) item about leaving lights on empty classrooms that appeared in each of the Korean assessments. This item was designed to assess students' sense of personal responsibility, and was measured using a four-point scale (3rd M = 2.96, 7th M = 2.83, and 11th M = 2.21, all which were between "disagree" and "agree"). A second comparison was on an item in the seventh-grade and the eleventh–grade assessment in Korea that pertained to wearing warm underclothes in winter to save on energy (7th M = 2.60 and 11th M = 2.27, on a 4-pt. scale, both of which were between "disagree" and "agree"). On both of these items, the decline in mean scores over successive grades appears to be consistent with the pattern found in items that assessed students' dispositions toward modes of transportation other than cars. This pattern also was apparent in results on both of the items in the U.S. assessment. However, the results on the two items in the U.S. assessment also indicated that students in both the sixth- and eighth-grade sample were more willing the use dimmer light bulbs (6th M = 3.70 and 8th M = 3.53) than to use less air conditioning (6th M = 3.42 and 8th M = 3.22, both on a 5-pt. scale, with both means falling between "not sure" and "mostly true"). The only other comparison that might be made is between the item in the U.S. assessment pertaining to air conditioning and the item in the Korean assessment pertaining to wearing warmer clothes (i.e., both are intended to save energy). The results on the Korean items on heating and U.S. item on air conditioning items appear to be comparable, although insights into the reasons for these moderate or mixed dispositions would likely require the collection of more in-depth interview data such as has been undertaken by Boyes and his colleagues (2011).

Finally, five items were used to assess (d) students' attitudes toward and willingness to reuse, engage in recycling, and purchase recycled/recyclable goods. One of these items focused on the recycling of aluminum appeared in each grade within the Korean assessment (3rd M = 3.13, 7th

M = 2.64, and 11th M = 2.47, on a 4-pt. scale, with values falling above "agree" to between "disagree" and agree", respectively). The item in the sixth-grade Israeli assessment focused on recycling a wider range of materials (M = 4.65 on a 6-pt. scale, which was between "fairly true" and "true"). One of the items in the U.S. assessment (27) was similar to this Israeli item, and the results for the sixth-grade U.S. sample were comparable to those for this Israeli sample (6th M = 3.74, on a 5-pt. scale, or below "mostly true"). Further, the decline in results over successive grades apparent in the Korean item on recycling (above) was apparent in the U.S. results on this item (8th M = 3.55 on a 5-pt.scale, which was between "not sure" and "mostly true"). The second item in the U.S. assessment that pertained to recycling focused on students' persuading others to do so (6th M = 3.70 and 8th M = 3.44), and the results on this item were only slightly lower than for the item regarding students' dispositions toward their recycling. The final item pertaining to recycling appeared in the assessment of fifth graders in Turkey, although this was a more general item pertaining to students' willingness to take actions to prevent environmental problems, with recycling as one of several examples. On the one hand, the results on this item (M = 3.46 on a 4-pt. scale, which was between "agree" and "strongly agree") reflect a stronger disposition than on any other recycling-related items among these samples. However, this might be attributable to the more general content in this item (i.e., preventing problems vs. recycling).

When the results on all four sets of items used to assess selected dispositions were viewed across grade levels and national assessments, two patterns were apparent. First, in the samples from Korea and the U.S., dispositions in lower grades were stronger when compared to those in upper grades. Second, in the samples from Korea, Israel, and the U.S., there was a more general tendency for dispositions toward recycling to be more positive than toward other more direct forms of energy conservation.

Comparison of results on selected behavior items across national assessments and grades. Team members chose to organize and summarize results for selected behavior items in three general areas related to climate change. These were: (a) behaviors aimed at conserving energy by using forms of transportation other than cars, notably those that would reduce carbon emissions; (b) behaviors aimed at conserving energy in buildings (e.g., used in lighting, for heating and cooling, by appliances); and (c) behaviors that involve reuse or recycling.

The results for selected behavior items in these three areas are summarized in Table 13 (p. 36). First, only one item within these national assessments was used to assess (a) students' behaviors that involved modes of transportation others than cars. This item appeared in the third-, seventh-, and eleventh-grade assessment, and pertained to walking, using public transportation, or biking instead of using a car (3rd M = 2.82, 7th M = 2.88, and 11th M = 2.85, on a 4-pt. scale). These values all fell slightly below "sometimes", and reflect negligible differences across these grades.

Second, six items within these national assessments were used to assess (b) students' behaviors that involved conserving energy in buildings (e.g., in households and schools). Two items pertained to students turning off lights. One appeared in the third-, seventh-, and eleventh-grade assessments in Korea (3rd M = 3.35, 7th M = 3.44, and 11th M = 3.27, on a 4-pt. scale). On this item, all values were above "sometimes", but also reflected negligible differences across these grades. The second of these items was used in the U.S. assessment (6th M = 3.96 and 8th M = 3.74, on a 5-pt. scale, which fell slightly below "mostly true"). A related-but-broader item was used in the sixth- and twelfth-grade Israeli assessments. It focused on conserving energy by turning off lights, turning up the air conditioner, and turning down the heater (6th M = 3.41 and 12th M = 3.39, on a 5-pt. scale, which fell between "sometimes" and "often"). The results on these items appear to be reasonably positive and consistent. Another item in the U.S. assessment focused on closing the refrigerator door while making a decision about what to eat or drink (6th M = 3.15 and 8th M = 2.81, on a 5-pt. scale, which were slightly above and below "not sure", respectively). The results on this item suggest that U.S. students were less prone to do this (where consequences are less visible) than they were to turn off lights (where consequences are more visible). Finally, an item in the fifth-grade Turkish assessment (B16) was even broader than the Israeli item (i.e., taking steps not to use electricity if it is not necessary), reflected a different kind of behavior than those noted above (i.e., persuasion of family members), and made use of a different type of measurement scale (i.e., ratio instead of ordinal). Despite these difference, the results on this item (M = 4.40, on a 7-pt. scale, which fell between 4-5 times in the last year) appear to be reasonably consistent on all of these other items, with the exception of the item in U.S. assessment pertaining to closing the refrigerator while deciding what they may want to eat or drink.

Table 13. Results for Selected Behavior Items across National Assessments and Grades

National Assessment	Korea			Israel		U.S.		Turkey
Grades	3rd	7th	11th	6th	12th	6th	8th	5th
Behavior	**Item # (Mean)[1]**							
A. Conserve energy/reduce emissions (transportation)	B3 (2.82)	B3 (2.88)	B3 (2.85)	-	-	-	-	-
B. Conserve energy/reduce emissions (buildings)	B11 (3.35)	B11 (3.44)	B11 (3.27)	19 (3.41)	21 (3.39)	37 (3.96) 43 (3.15)	37 (3.74) 43 (2.81)	B12 (5.04) B16 (4.40)
C. Reuse/recycle	B5 (2.84) B7 (2.77) B9 (3.00)	B5 (2.32) B7 (2.33) B9 (3.06)	B5 (2.11) B7 (2.11) B9 (2.99) B12 (2.26)	21 (2.36)	23 (1.96)	39 (3.48) 45 (3.43)	39 (3.16) 45 (3.29)	B9 (3.43) B13 (3.51) B17 (4.08)

[1] Mean scores fall along 4-point scale (Korea), 5-point scale (Israel), 5-point scale (U.S.), and 7-point scale (Turkey).

Third, 10 items within these national assessments were used to assess (c) students' behaviors associated with reuse and recycling. Five of these items pertained to student involvement in recycling. The most specific item appeared in the Korean assessment and pertained to recycling of aluminum (3rd M = 2.84, 7th M = 2.32, and 11th M = 2.11, on a 4-pt. scale, which ranged from slightly below "sometimes" to slightly above "rarely"). The item used in the sixth- and twelfth-grade Israeli assessment was broader, in that it focused on student recycling of batteries, cans, bottles, paper, and newspapers (6th M = 2.36 and 12th M = 1.96, on a 5-pt. scale, which were slightly above and slightly below "rarely", respectively). An even broader item was used in the U.S. and Turkish assessments. These items asked students how often they separated various materials for recycling. The results from the U.S. assessment (6th M = 3.43 and 8th M = 3.29, on a 5-pt. scale, which fell above "not sure"), and from the Turkish assessment (M = 3.43 on a 7-pt. scale, which fell between 3-4 times in the last year) appear to be reasonably consistent with results noted above for the Korean and Israeli samples, and suggest a less frequent involvement in recycling, with students in lower grades reporting that they do so more frequently than students in upper grades. In addition, one of the items pertaining to recycling focused on students' persuading others, in this case, family members, to recycle. The results for this item in the U.S. assessment (6th M = 3.48 and 8th M = 3.16, on a 5-pt. scale), follow this trend, and are similar to the results on the item about students recycling themselves.

Two of the remaining items pertained to student involvement in the purchase of goods that were made from recyclable materials or materials that could be recycled. One of these items was included in the assessment of fifth graders in Turkey (M = 3.51 on a 7-pt. scale, which fell between 3-4 times in the last year), and the other item was included in the assessment of eleventh graders in Korea (M = 2.26 on a 4-pt. scale, which fell slightly above "rarely'). These results appear to be reasonably consistent with each other and with the results on the recycling items described above.

The final three items pertained to student involvement in some form of reuse of existing goods. One of these items appeared in the each of the Korean assessments, and asked about students' reuse of cups, containers, and bags (3rd M = 2.77, 7th M = 2.33, and 11th M = 2.11, on a 4-pt. scale, which ranged from slightly below "sometimes" to slightly above "rarely"). These results

are very consistent with the results for these samples on the recycling item described above. Another of these items appeared in each of the Korean assessments, and this item focused on students' use of both sides of paper for writing or drawing (3rd M = 3.00, 7th M = 3.06, and 11th M = 2.99, on a 4-pt. scale, which ranged from slightly above to slightly below "sometimes"). While these results were consistent across grades, they were inconsistent with those described above. The final item pertaining to reuse was included in the assessment of fifth graders in Turkey. This item asked how often students donated items that were not in use to people and institutions in need (M = 4.08, which fell slightly above 4 times in the last year).

In summary, two patterns are apparent in the results on these selected behavior items. First, as described in the previous section for disposition items, in the samples from Korea, Israel, and the U.S., students' self-reported level of behavior in lower grades was greater when compared to the level in upper grades. Second, contrary to what was described in the previous section for disposition items, in the samples from Korea, Israel, and the U.S., the self-reported frequency of behavior was somewhat higher for energy conservation in buildings than for recycling.

Discussion

The *purpose* of this paper has been to summarize evidence pertaining to climate literacy variables drawn from four recent national assessments of environmental literacy. These efforts and this paper have addressed three different ways of looking at this evidence: (Question 1) evidence from each of these national assessments; (Question 2) evidence for elementary, for middle, and for secondary grades; and (Question 3) evidence gathered from closely related items across both national assessments and grades. Thus, the three major *delimitations* apparent in this paper were: (a) the use of evidence from only these four national assessments of environmental literacy, and the grades included in each; (b) the inclusion of evidence for only those items deemed by the research team to be directly related to elements of the Climate Literacy Framework (U.S. Global Change Research Program/Climate Change Science Program, 2009); and (c) due to differences in assessment instruments and samples, the use of a narrative and

descriptive statistics, not inferential statistics, to present the results of and comparisons among these selected items.

As noted in the title of this paper, this summary of evidence does little more than provide glimpses into the status of climate literacy among K-12 students in these four nations because the primary purpose of each of these national assessments was to generate insights into environmental literacy rather than into climate literacy. While these two domains of literacy are related and overlap, they are not identical. This was readily apparent in Table 3 (p. 7). Within each nation- and grade-specific assessment instrument, the number of items used to assess any of the four major environmental literacy components that were deemed to be directly related to climate literacy ranged from a high of 10 to as few as two. As a result, the extent to which these four assessments could and did provide glimpses into climate literacy was limited. This serves as a prominent *limitation* of this paper.

There are two additional types of limitations that affected this paper. The first pertained to limitations apparent in these four assessments themselves. The most prominent of these limitations had to do with the use of self-reporting in the measures of behavior in each national assessment. The validity and reliability concerns that can arise with self-reporting and thereby can affect the quality of behavior results have been well documented. One of the research strategies that can be used to address these concerns involves the use of blind observers (e.g., Horsely, 1977; Ramsey, Hungerford, & Tomera, 1981), although this is rarely feasible in large-scale assessments such as those featured here. A second research strategy for addressing these concerns involves the use of several negatively worded items, or *wake-up items*, in a behavior scale. This strategy was used in the behavior scale in the U.S. assessment (see Table 9, p. 16), but not in the behavior scale(s) used in the other three national assessments. A third research strategy for addressing these concerns involves the use of *foil items* (e.g., items that measure unrelated behaviors, whose results also can be compared to those for environmental behaviors included in the scale). This strategy was not used in any of the national assessments. Thus, while the results for selected behavior items may provide some initial, useful insights into K-12 students' behavior, these concerns further limited the research team's ability to draw conclusions about students' behavior in at least three of these four national assessments.

The second type of limitation that affected this paper centered on differences in the items used in each national assessment. Within the U.S. assessment, both sixth- and eighth-grade samples were administered the same instrument. However, within the Korean assessment (Tables 4-6, pp. 9-12) and Israeli assessment (Tables 7 and 8, pp. 14-15), some, but not all, items appeared in the instruments administered to students in different grades. Thus, for some items comparisons across grades could be made, and for other items unique to each grade-specific instrument, they could not. However, this limitation was compounded when attempts were made to compare results on items across national assessments. As noted in the *Results for Question 2* and *Results for Question 3* sections, scales and items differed across these national assessments in a number of ways. For items used to assess each of the three components of environmental literacy, this included differences in item content, level of specificity (i.e., from general to very specific), and apparent level of difficulty (i.e., % correct). For items used in disposition and behavior scales, this included differences in the type of measurement scale used (e.g., ordinal vs. ratio) and in the range of scale values used (i.e., both numbers and labels assigned to points along a scale). When combined and viewed as a whole, these scale and item differences often rendered it difficult, if not impossible, to make meaningful comparisons across these four national assessments. For this reason, the results of the comparisons of related items are presented in narrative form and in tentative terms.

A summary of findings is offered below with this purpose, these delimitations, and these limitations in mind. These findings are tied to the samples from these national assessments in order to avoid the tendency to generalize or over-generalize them. These findings are presented for each question (see p. 3), starting with Question 1, which pertains to findings within these national assessments.

A. Results on the Israeli and U.S. assessments indicated that students in upper grades tended to be more knowledgeable than students in lower grades. As noted earlier in the paper, this pattern is reasonable based on developmental and educational factors. While this general scoring pattern was not as apparent in the Korean assessment, it was apparent in the subset of knowledge items directly related to climate change in that assessment.
B. The results on the Korea, Israeli, and U.S. assessments indicated that students' disposition scores were higher or more positive than were their behavior scores, regardless of grade level.

C. For these same three national assessments, students in lower grades tended to have higher disposition and behavior scores than did students in upper grades. This tendency is readily apparent in the results for the third-, seventh-, and eleventh-grade samples in the Korean assessment.

In addition, the following findings emerged from analyses of assessment results within each grade levels pertinent to Question 2.

A. For the **elementary-level** samples from Korea and Turkey, students' general level of environmental *knowledge* tended to be moderate, and their level of knowledge about climate change tended to vary from low to high depending on the content featured in the selected items. These students' general *dispositions* toward the environment and dispositions toward aspects of climate change tended to be quite positive. Their level of self-reported environmental *behavior* tended to be moderate ("sometimes"), although their level of behavior related to climate change tended to be slightly higher. Finally, while the Turkish fifth-grade sample appeared to be more knowledgeable than the Korean third-grade sample, there were no apparent differences between these two samples on scales and selected items pertaining to dispositions and behavior.

B. For the **middle-level samples** from Korea, Israel, and the U.S., students' level of general environmental and climate-relevant *knowledge* was similar to that reported for elementary-level samples, above (i.e., moderate). The U.S. eighth-grade sample appeared to be most knowledgeable about basic science concepts, while the Korean seventh-grade sample was more knowledgeable than Israeli sixth-grade sample on global warming and ozone depletion. These students' *dispositions* toward the environment and toward specific aspects of climate change tended to be positive. Finally, these students' level of self-reported environmental *behavior* tended to be moderate ("sometimes"), although across samples, students appeared to be more prone to take steps to conserve energy than to engage in recycling or reuse (i.e., conserve material resources).

C. For the **secondary-level samples** from Korea and Israel, students' level of environmental and climate-relevant *knowledge* was similar to that reported for elementary- and middle-level samples, above (i.e., moderate). The Korean eleventh-grade sample appeared to be more knowledgeable than the Israeli twelfth-grade sample on global warming. These students' *dispositions* toward the environment and toward specific aspects of climate change tended to be mixed and less positive (i.e., ranging from below "disagree" or "not true" to slightly above "agree" or "true"). While the Korean eleventh-grade sample showed more favorable dispositions than the Israeli twelfth-grade sample toward using modes of transportation other than cars, the reverse was true regarding the regulation of polluting industries. Finally, these students' level of self-reported environmental *behavior* tended to be relatively low (slightly below to slightly above "rarely"), and their level of behavior regarding specific aspects of climate change tended to vary from low to moderate. As was apparent for dispositions, both samples tended to engage in energy conservation at a moderate level, but more frequently than in recycling or reuse.

Finally, the following findings emerged from analyses of comparable items across national assessments and grade levels pertinent to Question 3.

A. Results for all samples on items pertaining to students' **knowledge** of climate change indicated that students' knowledge of ozone depletion (57.5% to 80.6%) was substantially higher than their knowledge of global warming (29% to 53.7%). Students' performance on items pertaining to knowledge of Earth and ecological systems tended to exhibit less item-to-item variability and a higher percent correct in upper grades in the Korean, Israeli, and U.S. samples (Table 11, p. 29). However, students in the fifth-grade Turkish sample performed better than other elementary- and middle-level samples on items in this area, which might be attributable to a close relationship between Turkish items and the National Science Curriculum. On the other hand, student performance on items pertaining to areas in the environmental sciences tended to vary considerably from item to item. Within the Korean, Israeli, and Turkish samples, the percent correct on these items varied as much as 38% and 48% (i.e., from the lowest to the highest % correct).

B. Results on items pertaining to students' **dispositions** toward climate change indicated that for samples from Korea, Israel, and the U.S., student in lower grades tended to be more favorable toward modes of transportation other than cars than students in upper grades, and that the Korean samples were more favorable toward this than the U.S. and Israeli samples (Table 12, p. 29). On the three items that assessed students' dispositions toward regulation of polluting industries, the twelfth-grade Israeli sample was much more favorable than either the seventh- or eleventh-grade Korean samples. On items that pertained to conserving energy in buildings (e.g., residences, schools), students in the Korean and U.S. samples appeared to be moderately disposed to turn off lights in rooms not in use or use dimmer light bulbs, but less disposed to alter habits associated with heating and air conditioning. Finally, there was tendency for dispositions toward recycling to be more positive than toward other direct forms of energy conservation in the Korean and Israeli samples and, to a lesser extent, in the U.S. samples.

C. Results on items pertaining to students' **behavior** toward climate change indicated that students in lower grades scored higher than students in upper grades on comparable items. In addition, these items tended to reflect similar content to that found in items used to assess students' dispositions (Table 12, p. 29 and Table 13, p. 36). On the item pertaining to the use of modes of transportation other than cars, results for the Korean samples were moderate (below "sometimes"), and these means were lower than on parallel disposition item. On items pertaining to conserving energy in buildings, the results indicated that all sample(s) tended to be somewhat more active (i.e., greater than "sometimes", slightly below "mostly true", or 4-5 times in the past year). The notable exception to this was the results on the item in the U.S. assessment pertaining to students' avoidance of refrigerator gazing (slightly above and below "not sure"). For the Korean samples, those means were higher than on the parallel disposition items, one of the few times this was observed in these data. Finally, the results indicated that all samples tended to be moderately active in recycling and reuse, but that this level of behavior was somewhat lower than their conserving energy in buildings.

There are numerous inferences that could be offered for some of these results, and for the apparent discrepancies within these results. However, in light of the limitations associated with these analyses, as well as the limited evidence about climate literacy at the K-12 level against which to compare these results, the team members chose to refrain from such speculation.

There are a number of recommendations that can and should be offered on the basis of the work embodied in this report. In light of the overarching research problem (see pp. 2-3), and the aforementioned delimitations imposed upon and limitations apparent in this paper, all of these recommendations will focus on research matters.

1. The methods used to select items for inclusion in this review (see pp. 5-7) and the final selection of items (see Tables 4 through 10) should be subjected to a careful review by professionals experienced in climate literacy and climate change education. This type of review has not been undertaken beyond the members of the research team, and would serve as a useful check on the findings reported above, as well as a check on these methods prior to their use (or adaptation) in any similar secondary analyses.

2. In light of the limited body of evidence about the status of climate literacy in the K-14 sector, comparable secondary analyses should be undertaken on existing and available data sets. This will require the identification of such international and national data sets, and should include those generated by PISA (e.g., OECD, 2009).

3. In the absence of any single large national or international assessment in the area of climate literacy, serious efforts should be made to identify, access, and review existing sources of data on K-14 climate literacy, as well as compare, integrate, and summarize what those data sets can tell us about the status of climate literacy in the K-14 sector. Ideally, such an initiative: (a) would be undertaken by a team of qualified education, assessment, and research professionals; (b) would involve a careful analysis of the quality of the evidence in each source of data (e.g., Rickinson, 2001); and (c) would be funded by any of the federal agencies that have an expressed interest in climate literacy and in the results of such an effort.

4. Ideally, the above steps should be taken prior to the design and conduct of any national assessment of climate literacy within the U.S. These and other steps would be useful to help: (a) clarify and refine a definition of the domain of climate literacy; (b) determine apparent gaps within existing data sets (e.g., by age/grade level and by components within that domain); and (c) within these data sets, evaluate the relationship among item content and phrasing, item format, and item results. With this prior work in mind and in place, it would be more feasible to design and develop instruments for a large-scale national assessment of climate literacy within targeted age/grade levels. The extent to which such instruments should be tied to national curriculum standards (e.g., NAEP) and should not be (e.g., PISA), and whether these instruments should be administered via pencil-and-paper or electronically, should be part of such a deliberate instrumentation process (i.e., weigh the relative limitations and benefits of each).

5. To help ensure that the data to be gathered by any such climate literacy assessment instrument(s) would be usable, each instrument should be piloted with its target audience to ensure the psychometric properties of that instrument (e.g., internal consistency and stability, content and other appropriate forms of validity). Any necessary modifications should be made to each instrument prior to further administration.

6. Once high-quality assessment instruments are available, a national assessment of climate literacy in these targeted grade levels should be planned and conducted. If one of the major purposes of such an assessment would be to establish a baseline measure of climate literacy against which later national and state assessment results can be compared, then it would be appropriate to select and use an appropriate sampling and data preparation strategy (e.g., probability-proportional sampling and weighting data sets to reflect national population data, as in McBeth et al., 2008).

7. One of the numerous benefits of having a baseline measure of climate literacy is that it would allow educational programs that are designed to advance climate literacy to compare how students in their programs compare to that national baseline. Within this in mind, efforts should be made to develop a national database for K-14 schools that offer exemplary climate literacy programs and that use exemplary climate literacy educational materials. The programs in this

type of database could then serve as the basis for generating samples in a follow-up study to a national baseline study (i.e., a purposive sample, as in McBeth et al., 2011). This would allow the relative effects of all school programs and each cluster of programs in such a follow-up study to be compared to the national baseline. In turn, this would then serve as an index and indicator of the relative educational benefits of these K-14 climate literacy programs and materials.

8. There are a number of additional factors that could influence the results in follow-up studies and baseline comparisons. Some of these factors may be educational in nature (e.g., the nature and extent of attention to climate literacy in a school's curriculum, teachers' background in content and pedagogy, the methods that teachers use in their classrooms, teachers' use of climate-related instructional materials other than those deemed exemplary, other educational opportunities related to climate literacy available to students), others may be socio-demographic (e.g., the location and size of the community served by the school, the economic and ethnic composition of that community, parental educational and economic characteristics), and still others the interface between these (e.g., the size of the school, the school budget, teacher : student ratios, Principal leadership, community attitudes). For this reason, additional demographic and experiential data relevant to schools, programs, teachers, parents and families, and students should be collected as part of national baseline studies and follow-up studies of selected educational programs (e.g., as in OECD, 2006, 2009; McBeth et al. 2008, 2011). These data should be analyzed carefully to determine the extent to which these factors may be helping and hindering the development of climate literacy among K-14 youth in the U.S., whether as part of these studies or in a more in-depth secondary analysis of study data.

Once the kinds of assessment and research evidence alluded to in these recommendations have been gathered and analyzed in a deliberate and systematic manner, this wider body of evidence should provide valuable insights that can be used to identify best practices in/for climate literacy at the K-14 level, as well as advance K-14 educational practices in relevant areas (e.g., teacher preparation and professional development, development of materials, design of school scope-and-sequence plans, selection and use of instructional strategies with different kinds of learning outcomes in mind, formation of school-community partnerships, and so on). To advance K-14

educational practices in these and others areas, we need more, varied, and better data to inform our thinking and guide our decisions.

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