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# The Effects of Earth Science Textbook Contents on High School Students' Knowledge of, Attitude toward, and Behavior of Energy Saving and Carbon Reduction

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ABSTRACT: As science textbooks are considered as one of the major source of climate change information of students, this study aims to examine the differences in energy saving and carbon reduction knowledge, attitude, and behavior between two groups of Taiwan's high school students using earth science textbooks of two different publishers. Some items of knowledge, attitudinal, and behavioral subscales reflecting significant differences largely coincide with the differences in the coverage amount, text specificity, and picture presence in relevant contents between two textbooks. Students using the textbook with those features performed better on most of those items, including higher percents correct of identifying types of radiations and greenhouse gases and stronger support for more wind power generators. Behavioral effects of the two textbooks seem comparable between two groups of students.

KEY WORDS: textbook, content analysis, energy saving, carbon reduction, climate change

## INTRODUCTION

Energy saving and carbon reduction (ESCR) has been widely accepted as necessary actions to alleviate problems of climate change particularly in Taiwan. Educational authorities and governmental agencies devoted to the promotion of ESCR-related knowledge, attitude, and behavior in educational systems with a variety of materials among which science textbooks are a media reaching and in immediate contact with every high school student. In practice, teachers of curriculum development committee of a disciplinary field, such as natural science, mathematics or art,

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evaluate textbooks of different publishers and select one to be formally used in the teaching in their high schools.

All high school students in Taiwan participated in the Comprehensive Assessment on fundamental disciplines including natural science when they were graduated from junior high schools. Teaching for these ninth-graders in junior high schools focuses on the preparation for the assessment. Besides, it has long been a custom that most junior high school students spend extra time learning in cram schools under parental expectations to get higher assessment scores. As a result most high school students possess basic knowledge in natural science, particularly those in major cities. Different textbooks adopted by high schools are among the heterogeneous factors affecting the academic performance of these students who went through the same preparation stage for the assessment.

Climate is one of the major topics in earth science and currently there are four publishers that publish high school earth science textbooks, which differ in the ESCR-related contents in terms of the amount of coverage. This background draws our attention to the potential that earth science textbooks of different publishers might have in instilling knowledge, forming attitude, and advocating behaviors regarding ESCR in high school students. In a science textbook and the settings of formal education, ESCR-related contents are conventionally given minor emphasis and with limited coverage, particularly the attitudinal and behavioral contents, due to the exam-led teaching practice. Still, these contents are apparently necessary for an island susceptible to natural disasters of climate change and students need to be literate in this issue in a global context.

Rather than a content analysis that simply presents quantitative differences in topical contents between textbooks, this study goes further to explore whether the content differences are linked with the differences between two groups of students using different textbooks regarding what they know, feel, and do about ESCR. Differences in this regard found in these students should be informative for earth science teachers who may supplement teaching with additional materials and adjust pedagogy as well as textbook editors who deem textbook capable of more than disseminating knowledge.

## LITERATURE REVIEW

An individual considered literate about climate change should understand the Earth's climate system, be able to assess whether new climate information credible and take responsible actions based on informed decision (Climate Change Science Program, 2009). The argument of

Schreiner, Henriksen, and Kirkeby Hansen (2005) echoes this definition, indicating that sufficient knowledge as well as adequate actions are required to face climate change issues. For the purposes of the present study, an overview of what high school students know about, what attitude they hold toward, and what they do for these issues would be necessary and informative as to the influential role that textbooks should play.

### *Knowledge*

Nowadays, messages of climate change disseminated through mass media, and by school teachers as well, have reached most high school students who hence are inculcated with different forms of knowledge about climate change. As Fortner (2001) and Schuster, Filippelli, and Thomas (2008) indicated, media, advertising, and environmental consumerism are the sources of information from which most students' understanding of climate change comes though the information presented from these sources might be simplified and even inaccurate. Half of the Australian secondary students investigated by Boyes, Skamp, and Stanisstreet (2009) considered themselves informed about global warming. However, what they have learned about climate change could be superficial and suffered misconceptions that themselves are unaware of. What counts more, as advocated by Keeling et al. (2010), should be students' abilities to apply scientific reasoning in investigating and making decisions about the issues of human impacts on carbon and climate. It is pointed out that to have scientific discussions on carbon cycle and human interference in it is difficult for high school graduates (Keeling et al. 2010; Jin & Anderson, 2012), which could be resulted from their lack of sufficient scientific knowledge to comprehend the complexities of climate change and make informed decisions regarding their impacts on climate (e.g., Lee et al., 2007; Lester, Ma, Lee, & Lambert, 2006; Österlind, 2005).

Students' understanding of climate change could be seriously disturbed by associated misconceptions (Lester et al., 2006; Andersson & Wallin, 2000; Boyes & Stanisstreet, 1993, 1998; Francis, Boyes, Qualter, & Stanisstreet, 1993), which many studies have investigated in the adolescences. Choi, Niyogi, Shepardson, and Charusombat (2010) compiled an overview of middle and high school students' misconceptions of climate change, being organized according to basic notions, causes, effects, and reduction/mitigation of climate change. Confusion between global warming and ozone layer depletion is one generally found in studies (Punter, Ochando - Pardo, & Garcia, 2011; Liarakou, Athanasiadis, & Gavrilakis, 2011; Woods, 2010; Boyes,

Stanisstreet, & Yongling, 2008; Kılınç, Stanisstreet, & Boyes, 2008; Daniel, Stanisstreet, & Boyes, 2004; Rye, Rubba, & Weisenmayer, 1997). Other common misconceptions include: confusion about the types of greenhouse gases, for example, not considering water vapor as a greenhouse gas (Punter et al., 2011; Schreiner et al., 2005); no distinction between UV and infrared radiation in indicating the radiation that greenhouse gases absorb (Boyes & Stanisstreet, 1998); considering general air pollutants as the cause of climate change (Andersson & Wallin, 2000; Gowda, Fox, & Magelky, 1997); and considering the greenhouse effect an environmental problem (Myers, Boyes, & Stanisstreet, 2004). Some of these conceptions might have existed since their childhood or early adolescence as other studies that investigated elementary and secondary school students found (e.g. Reinfrieda, Aeschbacher, & Rottermann, 2012; Österlind, 2005; Koulaidis & Christidou, 1999; Boyes & Stanisstreet, 1993, 1997). Nevertheless, Boyes et al. (2008) found that as students aged their scientific ideas mostly increased and misconceptions decreased. McCaffrey and Buhr (2008) addressed these misconceptions from a perspective of system holes in education and communication and argued that people's confusion in this regard could be caused by biased information in mass media along with the insufficient science education.

### *Attitude*

In this study, the subject matter toward which an individual holds a attitude is not climate change itself. Rather, it refers to the extent to which his or her approval or disapproval of the seriousness of the problems caused by, necessity of mitigating of, and effectiveness of certain solutions of climate change. Shepardson, Niyogi, Choi, and Charusombat (2011) found from their qualitative data that some US students had reservations about the major impact of climate change on people or society. In a high school in UK, there were 51% of students who agreed or strongly agreed with a statement that climate change might not be as bad as people say and only 23% thought that climate change is very important to them (Woods, 2010). On the contrary, Boyes et al.'s (2008) finding revealed that more than 90% of the students were a little or very worried about global warming. As many as 87.59% of the students believed that extreme weather events will become more frequent (Liarakou et al., 2011). High school or secondary students who believed that global warming was already happening account for large proportions of the students investigated such as 75% (Boyes et al., 2009; Woods, 2010) and 86% (McNeill & Vaughn, 2012) but a smaller proportion of 54% for American teens (Leiserowitz, Smith, & Marlon, 2011). There seemed to

be a considerable number of students who doubted human contributions to climate change. In Woods' (2010) investigation, for example, only half of high school students thought of climate change as anthropogenic, implying that the acceptance of climate change could suffer from the undermining effects of misleading and cherrypicked data (Clark, Ranney, & Felipe, 2013).

Renewable energy is as well a subject toward which students hold an attitude in ESCR reduction. Halder et al. (2012) found in an international survey that youth had a fairly positive attitude toward renewable energy, in particular, common sources such as wind and solar energy. Recent quantitative findings in individual countries conform to this. Over 80% of Jordan high school students approved of the utilization of renewable energy (Zyadin et al., 2012). Considerable percentages of the counterparts in American (83%, DeWaters & Powers, 2011), Chinese (82%, Boyes et al., 2008), Australian (69%, Boyes et al., 2009), and Greek (64.18%, Liarakou et al., 2011) believe that using more renewable energy could help alleviate global warming. Most British students also agreed this idea (Daniel et al., 2004). Their attitudes toward energy saving behavior with respect to reducing global warming seem relatively reserved. Take saving electricity for example, there were 41% of British high school students considering it correct (Daniel et al., 2004), about half of Chinese students (Boyes et al., 2008) thought it helpful, while 62% of Turkish students believed it and other behaviors such as using fuel-efficient cars (53%) and improving home insulation (49%) to be useful (Kılınç, Boyes, & Stanisstreet, 2011). A similar conservative percentage was also found for transport-related behavior. There was 54.96% of Greek students believing using public transport helps mitigate greenhouse effect (Liarakou et al., 2011), compared with certain behavior widely deemed environmental-friendly such as. planting more trees which was believed helpful by 89% of high school students in China (Boyes et al., 2008). Toth et al. (2013) indicated that the location of energy use and sources of information could affect students' energy attitude and their ages made differences between the foci of their concerns, though a few studies obtained mixed results (e.g., DeWaters & Powers, 2011; Kılınç et al., 2011).

### *Behavior*

Common behaviors that students undertake to save energy can be categorized into household- electricity- and transportation- related behaviors. Cornelius et al. (2014) and DeWaters and Powers (2011) investigated American high school students and found they 0.775 of the time or 68.6% of them would turn off the lights when leaving a room; most of them would leave a computer on with monitor off or put the

computer to sleep or 34.9% of them would turn it off when not using it; 0.658 of the time they would switch off appliances; and 0.308 of the time, they would use a clothesline or hanger to dry clothes instead of a clothes dryer. About 27% of the students interviewed by McNeill and Vaughn (2012) claimed that they turned off lights and unplugged appliances and 5% used compact fluorescent light bulbs. As regards transportation-related behaviors, American students had 3.33 car trips from home to school every week (Cornelius et al., 2014) and 45.5% of them would walk or bike to go short distances (DeWaters & Powers, 2011). In Australian, 51% of high school students were willing to use smaller, more fuel-efficient cars, 17% public transport and only 20% would reduce eating meat (Boyes et al., 2009). These measures suggest that situational factors could be a major determinant of energy-saving behaviors. Kılınç et al. (2011) envisaged that personal convenience in different situations could lead to the popularity of turning off un-used appliances and the relatively low acceptance of using public transport. Measurements of high school students' actual energy consumption scarcely exist. For example, Danish teenagers used 20% more electricity than adults (Gram-Hanssen, 2005); American high school students consumed between 200 and 800 kilowatt-hours of electricity per year (Jaramillo, Marriott, & Matthews, 2008).

### *Influences of textbooks*

Scientific concepts of students generally come from science textbooks (Fulp 2002; Weiss et al. 2002) and they are the main didactical mediators in science teaching (Izquierdo, Sanmartí, & Espinet, 2008). This is particularly true for high school students in Taiwan who spend most of their time in schools and cram schools. Teachers regularly depend on textbooks in teaching as well. A survey of Trends in International Mathematics and Science Study revealed that on average 40% of the time in teaching a lesson teachers use textbooks (Martin, Mullis, & Foy, 2008). As a result, textbooks might have effects on students' knowledge of ESCR. Pictures are commonly believed to be more convincing than texts. As Devetak and Vogrinc (2013) suggested, it is better to present texts and pictures together in a textbook. It must be cautioned how pictures are presented could have side effects. Shepardson et al. (2011) pointed out that the images and diagrams presented in many secondary earth and environmental science textbooks could re-enforce some misconceptions of climate change, though it needs empirical verification. In fact, evidences of the influences of science textbooks on students' attitude toward and behavior of environmental issues are also scanty. It is these evidences that the present study was conducted to provide.

## METHODOLOGY

### *Content analysis*

Two basic earth science textbooks of publisher L and publisher N were selected for their large shares in the market of high school earth science textbooks. Five experts of professors and experienced school teachers collectively enumerated keywords relevant to ESCR, accordingly reviewed the two textbooks and identified the relevant contents which were categorized into knowledge, attitudinal, and behavioral contents. These contents, both texts and figures, were measured in pages that can be converted to percentages by being divided by total number of pages of the textbook. The experts discussed results of their identification before the identified content percentages were averaged by number of experts. Below are the keywords that experts used to identify ESCR contents:

- Energy area: energy, renewable, reduction, solar, wind, hydraulic, geothermal, power, electricity, oil, petroleum, gas, transportation, biomass, alcohol, fossil, nuclear, efficiency, and fuel.
- Climate area: climate, weather, warming, greenhouse effect, carbon cycle, carbon dioxide, methane, ozone, infrared radiation, albedo, sea level, ultraviolet, disaster, debris flow, landslide, drought, flood, rain, precipitation, cyclone, typhoon, storm, ice, glacier, polar bear, arctic, antarctic, and land use.
- Education area: knowledge, awareness, attitude, seriousness, urgency, skill, action, save, mass transport, cycling, limit, resource, protection, conservation, consumption, emission, light, sustainable, and industry.

### *Participants*

With the research purpose of comparing the effects of earth science textbooks of two major publishers, L and N, on students' knowledge, attitude, and behavior, students whose schools adopting these textbooks were certainly the participants of this study. Based on an investigation of those high schools, 48 students from 5 schools that adopt the textbook of publisher L and 38 from 7 schools that adopt textbooks of publisher N were sampled. All these 12 schools are co-ed and located in major cities and these students were all eleventh-graders who were approached through places around their schools, cram schools, and researchers' networks. They were asked to fill out the questionnaire in which textbook covers of different publishers were printed to be identified as the textbooks they used. Responses to the questionnaire item of textbook

cover identification serve as a selection criterion and those who identified textbook covers of publishers L and N were included in the student sample. Interactions between the two groups of sampled students should be minor since these schools are located in different cities across the country.

### *Questionnaire*

A questionnaire was developed to collect students' knowledge of, attitude toward, and behavior of ESCR and composed of five parts: a test of 13 questions about topical knowledge, an attitudinal scale with 12 items, a behavioral scale with 7 items, a behavioral intention scale with 7 items. All items use a five-point Likert-type scale. The Cronbach's α reliabilities are 0.71 for attitudinal, 0.74 for behavioral and 0.77 for behavioral intention scale.

### *Statistical analysis*

This study aims to examine differences in knowledge of, attitude toward and behavior of ESCR between two groups of students of two high schools that adopted different basic earth science textbooks. As knowledge questions in the questionnaire are multiple choices with restricted answers such as A, B, C, and D or more, for each knowledge questions, Chi-square tests were employed to distinguish differences in the proportional distributions of answers between two groups of students. Since responses to attitudinal and behavioral items are in five-point Likert-type scale, differences in attitude and behavior between the two groups were detected with independent sample t-tests.

## RESULTS AND DISCUSSION

### *Content analysis*

The basic earth science textbook of publisher N has more ESCR content than that of publisher L (Table 1) in all three categories of knowledge, attitudinal and behavioral contents. About twice as much percentage of ESCR content was identified in the textbook of publisher N (13.60%) as in that of publisher L (6.88%) but as expected most of the contents both textbooks contain are ESCR knowledge.

**Table 1. Content analysis of energy saving and carbon reduction (ESCR) in two earth science textbooks**

| | Pages with ESCR content | | | | Textbook | |
|---|---|---|---|---|---|---|
| Publisher | Knowledge | Attitudinal | Behavioral | Sum | pages | Percentage |
| L | 27.45 | 1.45 | 0.67 | 29.57 | 430 | 6.88% |
| N | 46.06 | 3.34 | 6.89 | 56.29 | 414 | 13.60% |

### *Overall differences*

The total score of all 13 knowledge questions, mean of the scores of all 12 attitude items, and mean of the scores of all seven behavior items, as Table 2 shows, are not significantly different between the two groups of students using textbooks of two respective publishers.

**Table 2. Overall differences between two groups of students using textbooks of two respective publishers**

| | Mean | | Difference between means |
|---|---|---|---|
| | L publisher | N publisher | |
| Knowledge (Total score) | 14.46 | 14.71 | -0.25 |
| Attitude (5-point scale) | 3.59 | 3.57 | -0.02 |
| Behavior (5-point scale) | 4.40 | 4.40 | 0.00 |

*Knowledge difference*

Table 3 presents the results of Chi-square tests of all 13 questions about science and issues in ESCR. A statistically significant Chi-square value ($\chi 2$) indicates the proportional distributions of answers to a question between the two groups of students are different. With a statistically significant level of 0.05, none of the questions reaches the level, meaning that the two groups of students using textbooks of two respective publishers did not differ in these knowledge questions.

Nevertheless, question 6 is noticeable for its p-value (0.053) almost reaches the statistically significant level. A larger proportion (37.50%) of students using textbook of publisher L knew that it is the infrared rays Earth's surface emits that green house gases mainly absorb and hence cause temperature rise, compared with about a half smaller proportion (18.42%) of students using textbook of publisher N knowing that. It was found, through a detailed inspection on the contents of both textbooks, that it could be a result of the specificity of the involved gases and

radiations in the texts of relevant explanation. In the textbook of publisher L, it is explained as follows:

> … the Earth's surface … radiates energy outward in the form of infrared rays … **infrared radiations** … are mostly *absorbed by the greenhouse gases* in the atmosphere.
> (Lines 5-8, page 61, Chapter 3. Italic emphasis added.)

As above quotation shows, both greenhouse gases and infrared rays are specifically stated; the term infrared radiations is even stressed in bold. While in the textbook of publisher N, the texts of explanation read relatively broad:

> … the Earth's surface … radiates **long-wave radiation** outward … are partly *absorbed by the atmosphere* … the Earth hence becomes warm.
> (Lines 5-7, page 151, Chapter 8. Italic emphasis added.)

Infrared rays are not mentioned in the texts and instead it stresses the term long-wave radiation in bold. It neither indicates what gases absorb the long-wave radiation, probably leading to the unfamiliarity of students who used this textbook with the fact that it is infrared rays that greenhouse gases absorbed. Confusion about the different radiations involved in the greenhouse effect has been noticed (Shepardson et al., 2011) and textbooks with explicit explanations should help clarify it.

Consistent with the findings of other studies (Punter et al., 2011; Boyes & Stanisstreet, 1993, 2001; Schreiner et al., 2005), carbon dioxide remains the most well-known greenhouse gas among students. The proportions in the results of Question 12 indicates that it is the greenhouse that almost all students know, with 89.58% and 97.37% of students using textbooks of two respective publishers choosing it as a greenhouse gas, compared with 72.34% of their Greek counterparts (Liarakou et al., 2011). Unlike other studies (Schreiner et al. 2005; Punter et al., 2011) indicating that water vapor is less well-known by students as one of the greenhouse gases, there were considerable students (about 60%) using textbooks of both publishers knowing that. Students using a textbook of publisher N seem to know the types of greenhouse gases better than those of publisher L as larger proportions of them chose the correct gases and smaller proportions of them chose the wrong gases in Question 12. Though the difference in these proportions between the two groups of students is not statistically significant, the relevant contents specifically mentioning those greenhouse gases in the textbook of publisher N in contrast to lack of such contents in that of publisher L supports this difference.

**Table 3. Differences in knowledge about energy saving and carbon reduction between two groups of students using textbooks of two respective publishers**

1. Which of the following energy sources is renewable?

| | **C.** Wind | A. Oil | B. Coal | D. Uranium | Others | $\chi^2$ |
|---|---|---|---|---|---|---|
| L | 93.75% | | | 6.25% | | 0.088 |
| N | 92.11% | | | 7.89% | | |

2. Which of the following fuel types of power generation is more prone to cause global warming?

| | **C**. Fire | A. Wind | B. Solar | D. Nuclear | Others | $\chi^2$ |
|---|---|---|---|---|---|---|
| L | 87.50% | | | 12.50% | | 0.580 |
| N | 81.58% | | | 18.42% | | |

3. Which of the following fuel types accounts for the largest proportion in Taiwan's power generation?

| | **C**. Fire | A. Wind | B. Solar | D. Nuclear | Others | $\chi^2$ |
|---|---|---|---|---|---|---|
| L | 79.17% | | | 20.83% | | 0.757 |
| N | 71.05% | | | 28.95% | | |

4. The atmospheric $CO_2$ concentration now is approximately _____PPM

| | A. 100 | E. 500 | B. 200 | C. 300 | **D.** 400 | Others | $\chi^2$ |
|---|---|---|---|---|---|---|---|
| L | 12.50% | | 22.92% | 18.75% | 14.58% | 31.25% | 3.970 |
| N | 18.42% | | 15.79% | 13.16% | 28.95% | 23.68% | |

5. Which of the following is a process that removes carbons from atmosphere?

| | **B**. photo-synthesis of plants | A. Burning fossil fuels | C. Fermentation of excretions of livestock such as cattle and pigs | D. Volcanic explosions | Others | $\chi^2$ |
|---|---|---|---|---|---|---|
| L | 89.58% | | 10.42% | | | 0.160 |
| N | 92.11% | | 7.89% | | | |

6. What is the radiation that green house gases mainly absorb and hence cause temperature rise of Earth's surface?

| | A. The ultra-violet rays that Sun emits | B. The ultra-violet rays that Earth's surface reflects | C. The infrared rays that Sun emits | **D.** The infrared rays that Earth's surface emits | Others | $\chi^2$ |
|---|---|---|---|---|---|---|
| L | 10.42% | 27.08% | 20.83% | 37.50% | 4.17% | 3.744[#] |
| N | 23.68% | 26.32% | 15.79% | 18.42% | 15.79% | |

7. Which of the following types of land cover has the smallest albedo?

| | A. Ice field | B. Park lawns | C. Sea surface | **D**. Asphalt roads | Others | $\chi^2$ |
|---|---|---|---|---|---|---|
| L | 16.67% | 31.25% | 8.33% | 37.50% | 6.25% | 6.159 |
| N | 5.26% | 36.84% | 18.42% | 26.32% | 13.16% | |

Note: Bold letters are correct answers.

[#] A p value (0.053) close to 0.05 and the Chi-square ($\chi 2$) value is computed with proportions of two categories of correct answer and other answer.

(Table 3 continues)

| | | | | | | |
|---|---|---|---|---|---|---|
| 8. Taiwan's national carbon reduction goal is set to | | | | | | |
| | **A**. return to 50% of the 2000 emission by 2025 | **D**. return to the 2000 emission by 2050 | B. return to the 2000 emission by 2025 | C. return to 50% of the 2000 emission by 2050 | Others | $\chi^2$ |
| L | 20.83% | | 43.75% | | 35.42% | 0.911 |
| N | 21.05% | | 52.63% | | 26.32% | |
| 9. Which of the following measures is a "mitigation" strategy? | | | | | | |
| | **A**. Developing green fuel vehicles | B. Increasing irrigation efficiencies | C. Heighten-ing levees | D. Developing vaccines for infectious diseases | Others | $\chi^2$ |
| L | 81.25% | | 18.75% | | | 0.487 |
| N | 86.84% | | 13.16% | | | |
| 10. What global warming melts and makes sea level rise is | | | | | | |
| | **B**. Land-based ice | A. Ice floating on the sea | | Others | | $\chi^2$ |
| L | 45.83% | | 54.17% | | | 0.350 |
| N | 39.47% | | 60.53% | | | |
| 11. The main causes of the aggravating global warming include (Multiple choices) | | | | | | |
| | **A**. Greenhouse gases emitted by industries | B. Ozone hole | **C**. Reduction of forest area | **D**. Exhausts of massive vehicles | | $\chi^2$ |
| L | 87.50% [a] | 72.92% [a] | 75.00% [a] | 83.33% [a] | | 1.070 |
| N | 92.11% [a] | 65.79% [a] | 84.21% [a] | 92.11% [a] | | |
| 12. Which of the following are greenhouse gases? (Multiple choices) | | | | | | |
| | A. Sulfur dioxide ($SO_2$) | **B**. Carbon dioxide ($CO_2$) | **C**. Methane ($CH_4$) | D. Nitrogen dioxide ($NO_2$) | **E**. Water vapor ($H_2O$) | $\chi^2$ |
| L | 35.42% [a] | 89.58% [a] | 77.08% [a] | 20.83% [a] | 60.42% [a] | 4.959 |
| N | 21.05% [a] | 97.37% [a] | 92.11% [a] | 21.05% [a] | 63.16% [a] | |
| 13. The impacts of global warming include (Multiple choices) | | | | | | |
| | **A**. Coastal land will be submerged by seas | **B**. Wildlife will be unable to adapt | **C**. Climate abnormality | **D**. Vectors and infectious diseases will increase | **E**. Food production shortage | $\chi^2$ |
| L | 87.50% [a] | 77.08% [a] | 87.50% [a] | 54.17% [a] | 56.25% [a] | 0.831 |
| N | 92.11% [a] | 71.05% [a] | 94.74% [a] | 50.00% [a] | 52.63% [a] | |

Note: Bold letters are correct answers.

[a] The proportion is calculated by dividing the number of students choosing that answer by the total number of students using a textbook of that publisher.

A common misconception of confusing the ozone hole with other causes of global warming is found in the result of Question 11. Surprisingly, there are a large proportion of students in both groups (72.92% and 65.79%) considering that the ozone hole aggravates global warming. Even interestingly, except Shepardson et al's (2011) study, results of this and other studies nearly coincide on the size of this proportion, namely two thirds of Kılınç et al. (2008) and 67.73% of Liarakou et al. (2011). Another misconception that previous studies rarely investigated emerges in the result of Question 10. For both groups of students, those who think the melting of floating ice on the sea rises the sea level are still more in number than those who think the melting of land-based ice does that. Since both textbooks lack the clarification of this misconception, it is speculated that the images of melting sea ice in mass media could have impressed students and instilled the message that it causes sea level rise in them.

Both groups of students were found to quite ignorant of the up-to-date issues about ESCR as results of Items 4 and 8 reflect that those who knew the answers were few. Though the texts relevant with Item 4 regarding the atmospheric CO2 concentration are provided in the textbook of publisher L, the proportion of its student users choosing the correct answer is only roughly half that of the publisher N's (14.58% and 28.59%). On one hand this could be due to that the unit of "ppmv" is used in the texts, which appears different from the PPM used in the questionnaire item and makes students hesitate over the answers. On the other hand, in publisher N's textbook, there is no texts mentioning the concentration data but a diagram of the atmospheric CO2 concentration curve in recent decades, possibly drawing students' attention on the final value of concentration the curve has reached. In addition, both groups of students were equally unfamiliar with Taiwan's national goal of carbon reduction, with approximately only one fifth of them choosing the correct answer.

*Attitudinal difference*

Only one item stands out in Table 4 presenting statistically significant difference between students with textbooks of publisher N and those with textbooks of publisher L. The latter agreed more (mean score 3.84) with building more wind power generators in place of fire or nuclear power plants than the former (mean score 3.37). On a five-point Likert-type scale, both groups of students expressed fairly high approval of the statements of most items as the mean scores above three for almost all items suggest. For example, most of them agreed the seriousness of the problem of Taiwan's high reliance on imported oil (Item 3), restrictions on carbon.

**Table 4. Differences in attitude toward energy saving and carbon reduction between two groups of students using textbooks of two respective publishers**

| Items | Mean | | Difference between means |
|---|---|---|---|
| | L | N | |
| 1. Despite heightened costs and prices of electricity, I approve electricity generated in more environmental friendly ways. | 3.83 | 3.79 | 0.04 |
| 2. In order to mitigate climate change, I approve restrictions on carbon emission even though it might weaken economy | 3.77 | 3.87 | -0.10 |
| 3. I think that Taiwan's high reliance on imported oil is a serious problem at present. | 3.90 | 3.89 | 0.00 |
| 4. If we make the best use of all sources of renewable energy, they are sufficient to supply for Taiwan's household electricity consumption. | 3.58 | 3.66 | -0.07 |
| 5. I approve building more wind power generators in place of fire or nuclear power plants. | 3.37 | **3.84** | -0.47* |
| 6. I support imposing tax on carbon emissions | 3.23 | 3.08 | 0.16 |
| 7. I think that global warming seriously threatens the existence of polar bears. | 4.36 | 4.16 | 0.20 |
| 8. Future technology can find new coal and oil reserves which supply for human needs for quite a long period of time. | 2.75 | 2.58 | 0.17 |
| 9. I feel that Taiwan is seriously damaged by climate change disasters. | 3.75 | 3.87 | -0.12 |
| 10. It is not yet certain that the problems of global warming are caused by man-made pollutions; they could be just natural phenomena. | 3.49 | 3.16 | 0.33 |
| 11. Building new nuclear power plant is necessary in case electricity supply shortage hinders economic development and people's living. | 3.39 | 3.37 | 0.02 |
| 12. Renewable energy has many limitations and a low efficiency; governments should not give priority to promoting it. | 3.64 | 3.53 | 0.11 |

* $p < 0.05$

Note: the bold number is the statistically higher score representing a more positive attitude.

emission (Item 2) and that governments should promote renewable energy (Item 12). These results show seemingly a pro-environmental attitude of the students but Item 8 with notable lower scores (2.75 and 2.58) reflects a problematic belief in the ability of future technology to improve the energy problems, similar to the finding of Shepardson et al. (2011) that students believed new technologies will be developed to help human survive the environmental changes.

The textbook of publisher N has a picture of wind power generator in an individual chapter in the end of the book that specifically and solely addresses the Earth's sustainable development, which is different from the scattered distribution of sustainable development information throughout different chapters in the other textbook of publisher L. Combining with its more coverage of sustainable development than that in the textbook of publisher L, we consider the textbook of publisher N is more effective in increasing a student reader's support for the actions of sustainable development, such as building more wind power generators. Item 7 regarding polar bears seriously threatened by global warming has the highest scores for both textbooks. Again, images in mass media could account for this because both textbooks do not show any pictures and texts of polar bears.

The second largest difference is presented by Item 10 regarding the belief in the human cause of global warming and it is worthy of discussion. Thought the difference is not statistically significant, the result is in accordance with the difference in the contents of two textbooks. There seems to be implicit reservations about the problems of global warming in the description about the topic in publisher N's textbook. For example, it states "… the highest temperature in recent thousand years. But there is no evidence or theory proving the phenomenon is caused by global warming neither observed data proving its association with greenhouse gases" and "The time period since human starts to predict weather and explore climate variations is extremely short in relative to the Earth's history and there are too many factors affecting climate change." Such a tone of the contents is absent in the other textbook and probably explains the more reserved attitude toward the human cause of global warming of students using a publisher N's textbook (a score of 3.16) than those using a publisher L's textbook (a score of 3.49).

*Behavioral difference*

Statistically significant differences between means are found for four items, 6, 7, 9, and 13. Students who used textbook of publisher N suggest their family shut down the engines of parked cars to reduce idling time and buy local foods to reduce carbon emission during long-distance

transport more frequently than students who used textbook of publisher L. The situation reverses for the behaviors of suggesting their family buy appliances with energy-saving labels and install a solar water heater. Very little is mentioned about behaviors to save energy and reduce carbon emission in the textbooks of both publishers. The textbook of publisher L contains only texts of "…when everyone uses one kilowatt-hour of electricity less, a coal mine fewer can be opened; when everyone uses a paper fewer, maybe a whole forest can be saved" without any picture about these behaviors. This could be associated with the more willingness of the students using it to suggest their family buy appliances with energy-saving labels than that of the students using the other textbook. On the contrary, though the textbook of publisher N has few sentences with abstract calls such as "...take actions to saving resources and love the environment", it presents a large picture of a solar-powered car and a picture of the board of gasoline prices of a gas station. These pictures may be relevant with the more willingness of the students using the textbook than that of those using the other textbook to suggest their families to conduct carbon reduction behaviors in transportation, i.e., to avoid car idling and reduce food mileage. However, since the two textbooks are even in the number of items with better performance than its counterpart and there could be other interfering factors, it cannot be concluded that either textbook is more influential for ESCR behaviors than the other textbook.

*The effects of teachers*

Since it is teachers that interpret and convey the contents of textbooks to students, they are to some extent influential to the ESCR knowledge, and arguably attitude and behavior of their students. As the students in this study were randomly sampled from different schools, their teachers were presumably a random sample composed of mixed genders, with different teaching styles and positions toward ESCR. With this design in sampling, the effects of teachers on student performance could be controlled for and the probability is secured for the differences observed in certain knowledge and attitude items between two groups of students to be attributed to the two different textbooks.

**Table 5. Differences in behaviors of energy saving and carbon reduction between two groups of students using textbooks of two respective publishers**

| Items | Mean | | Difference between means |
|---|---|---|---|
| | L | N | |
| 1. In public places outside schools, when there are both elevators and stairs available and nearby for moving between three floors, I choose to walk on stairs. | 4.94 | 5.05 | -0.12 |
| 2. Before I leave out, I turn off the computer if it is not transferring files or running time-consuming programs | 4.73 | 5.08 | -0.35 |
| 3. Before I leave rooms or classrooms, I turn off lights and electric fans. | 5.19 | 5.68 | -0.50 |
| 4. I try not to turn on an air conditioner at home and instead use electric fans first as possible as I can. | 4.42 | 5.08 | -0.66 |
| 5. I walk or ride a bicycle and avoid using private cars and motorcycles for a short distance. | 4.79 | 5.00 | -0.21 |
| 6. In proper weather conditions, I suggest my family shut down the engines of parked cars to reduce idling time. | 3.58 | **4.39** | -0.81* |
| 7. I suggest my family buy local foods in order to reduce the carbons emitted from long-distance transport of foods from other places. | 3.38 | **4.21** | -0.84* |
| 8. Hypothetical situation: If the light bulbs at home need to be replaced, I would suggest my family buy electricity-saving light bulbs. | 5.38 | 4.82 | 0.60 |
| 9. Hypothetical situation: If we need new appliances at home, I would suggest my family buy those with energy-saving labels. | **5.23** | 4.45 | 0.78* |
| 10. Hypothetical situation: Even if there is a tumble dryer available, I would give priority to allowing the washed clothes to dry naturally. | 5.56 | 4.82 | 0.75 |
| 11. Hypothetical situation: When the organizers offer both meat and vegetarian lunch boxes, I would choose vegetarian by reason of less carbon emission (instead of religious or health reasons). | 2.65 | 2.61 | 0.04 |
| 12. Hypothetical situation: If we need to buy a new motorcycle at home, I suggest my family buy an electric motorcycle. | 3.08 | 2.74 | 0.35 |
| 13. Hypothetical situation: If my family will move in a new house, I would suggest them buy and install a solar water heater. | **4.29** | 3.32 | 0.98* |

(Table 5 continues)

| Items | Mean | | Difference between means |
|---|---|---|---|
| | L | N | |
| 14. Hypothetical situation: When entering a hotel room that is so sweltering that I have to turn on the air conditioner, I would set the starting temperature at _____℃. | 25.29 | 25.18 | 0.11 |

* $p < 0.05$

Note: the bold numbers are the statistically higher score representing a more positive attitude.

## CONCLUSIONS AND SUGGESTIONS

Small but meaningful differences in knowledge of, attitude toward, and behavior of ESCR were found between the two earth science textbooks however the textbook with more relevant contents does not necessarily perform better. Differences in knowledge include that students using the textbook of publisher L had a clearer understanding of the radiation absorbed by greenhouse gases but those using the textbook of publisher N had higher percents correct on the identification of types of greenhouse gases. In both groups of students using two respective textbooks, considerable proportions of them had two misconceptions, the inclusion of the ozone hole as one of causes aggravating global warming and the consideration of floating sea ice as the cause of sea level rise, however the proportions were slightly smaller among students using publisher N's textbook. Results of attitudinal subscale indicate that the two groups of students differed in the extent to which they support building more wind power generators. Students using the N publisher's textbook expressed a stronger support for that; but meanwhile its implicit tone could have rendered them reserved about the anthropogenic causes of global warming. The two textbooks seemed to have their respective effects on students' different behavior of ESCR however they were equally influential in terms of the number of their better-performing items of the behavioral subscale.

Despite not all of these differences reaching a statistically significant level, they are consistent with the differences in the amount of coverage or features associated with the topics in the contents of two textbooks, including highlighted texts of radiation types involved in the greenhouse effect, an independent chapter focusing on sustainable development, and pictures of wind power generators and a gas station, which are all applicable to the explanation of results. Nevertheless there remain other

interfering or competing factors to be verified by further study. Besides, mass media might have played a role in the formation of climate change misconceptions as well as the increase of sympathy for the problems of global warming, i.e., the cases of mis-identifying floating ice as the cause of sea level rise and feeling for the plight of polar bears.

A few suggestions are proposed for teachers and textbook editors. Knowledge related to issues of ESCR could be linked to the awareness and concerns of climate change, it needs to be taught though it has being considered trivial by students for its minimum usefulness in heightening grades. Junior high school science teachers are suggested to teach the principles of the phenomenon that floating ice does not raise water level after it melts and apply it to the sea level rise in global warming. A separate chapter that specifically deals with the attitude and behaviors concerning the conservation of Earth's natural resources and the maintenance of sustainability should be necessary in an earth science textbook, so are the relevant pictures. Moreover, it is essential that students recognize how and what energy is used in one country could be linked to the stability of global climate while learning this scientific knowledge. Exercises in earth science textbooks engaging students in discussing ESCR from an international perspective should be effective in contextualizing energy science learning.

## LIMITATIONS

Due to a number of factors this study has limitations. With limited research resource, we obtained only a small sample size which led to limited statistical power. The reality that all high schools adopt one earth science textbook disenables us from arranging a control group composed of high school students using no textbook. Without the baseline data, the effects of textbooks cannot be further verified. This is also associated with the difficulties in controlling for the effects of media.

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