Chinese Grade Eight Students' Understanding About the Concept of Global Warming

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ABSTRACT
China is one of the world's biggest greenhouse gas emitters. Chinese students' awareness and understanding about global warming have a significant impact on the future of mankind. This study, as an initial research of this kind in Mainland China, uses clinical interviews to survey 37 grade eight students on their understanding about global warming, as well as their personal actions to combat it. Findings show that students know CO_2 and acknowledge the existence of global warming, but 94.6% of them have not formed scientific conceptual understanding or the ability to make scientific decisions to combat it. The study also shows that mass media, rather than science education, serves as the main source for students to obtain information about global warming. These results implicate that the concept of global warming must be added in science education and the teaching quality of scientific concepts must be promoted in Mainland China.
Keywords: global warming, scientific concept, scientific literacy

INTRODUCTION

This study surveys Chinese students' understanding about global warming as well as their personal actions to combat it. Global warming poses great challenge to people all over the world nowadays (IPCC, 2014). Countries around the world have unanimously adopted "taking urgent action to combat climate change and its impacts" as one of the seventeen sustainable development goals (United Nations, 2015). In order to cultivate a sense of responsibility and scientific literacy among future qualified citizens for the 21st century, many countries have made the awareness and mitigation of global warming main issues in primary and secondary schools' science education (Zeidler, 2014).

However, global warming has not been taken as a concept or topic in the science textbooks for Chinese students' compulsory education (MOE of China, 2015). That is to say, students in Mainland China are not directly learning the concept of global warming in their science classes, instead they are learning phenomena and concepts related to global warming, such as weather and climate, atmospheric composition and pollution, energy use and its

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State of the literature

- Global warming is a global issue. The previous studies on primary and secondary school students' understanding about the concept of global warming focus on three aspects: scientific mechanisms, influence factors and policy decisions.
- Clinical interviews and questionnaires are two kinds of approaches mainly used by previous researchers when they investigate students' understanding about the concept of global warming.
- Previous studies reveal that most students do not give a scientific explanation about the causes, the harms and the cures of global warming when they are surveyed. In addition, students' misconceptions of global warming are very difficult to change.

Contribution of this paper to the literature

- China is one of the world's biggest greenhouse gas emitters. Chinese children' understanding about and their skills of dealing with global warming have a significant impact on the future of mankind. This study is an initial research on Chinese school students' understanding about the concept of global warming.
- According to the findings of the study, there is an urgent need to incorporate global warming education into Chinese school curriculum and improve students' understanding about and their ability of mitigating global warming.
- Mass media, as the main source for Chinese students to obtain information about global warming, should pay attention to introduce the scientific mechanism of global warming in popular and easy-to-understand ways.

impacts, and the interplay between human activities and the environment (MOE of China, 2011).

According to official statistics released in 2009 from the International Energy Agency, China has overtaken the United States as the world's largest emitter in 2007 (IEA, 2010). As a developing country with a large population, China needs people across the country to work together to achieve the reduction of greenhouse gas emissions (Cheng, et al., 2013). Both Chinese children' understanding about the concept of global warming and their innovative problem-solving skills to mitigate global warming have a significant impact on the future of mankind.

In academic website ProQuest and China National Knowledge Internet (CNKI), neither research on students' understanding about the concept of global warming, nor research on students' science policy educations is found in Mainland China. This study, as an initial research of this kind, aims not only to survey students' understanding about global warming, but also to figure out students' awareness and ability to apply what they have learnt in science classes to the real world.

LITERATURE REVIEW

Contents of previous research

From the 1980s onward, previous researchers have studied primary and secondary school students' understanding about the concept of global warming. Those studies mainly focus on three aspects: scientific mechanisms, influence factors and policy decisions.

The first aspect of research contents studies how students use scientific mechanisms to explain global warming, which involves students' understanding about the concepts of greenhouse gas, greenhouse effect, solar radiation, energy and ozone layer, etc. (e.g., Visintainer and Linn, 2015). Researchers take real-life contexts to develop survey items, which mainly center on the causes and consequences of global warming (e.g., Shepardson, et al., 2011). Some researchers also evaluate students' reasoning ability when students use related concepts to explain global warming (Visintainer and Linn, 2015; Sadler, Barab, and Scott, 2007; Adams, 1998).

The second aspect of research contents studies students' understanding on how natural warming mechanisms are enhanced by anthropogenic processes. This aspect involves students' understanding on how various types of energy are used in daily life (e.g., Taber and Taylor, 2009). Through questions about the cures for global warming, researchers ask students to analyze, explain, or evaluate the relationship between human actives and global warming by considering real-life situations (e.g., Fason, 1996). Many researchers also focus on students' scientific attitudes, responsibility and behavior tendency towards global warming (e.g., Sah and Bellad, 2015).

The third aspect of research contents studies students' understanding about the roles of policy-making and some official institutes in combating global warming (e.g., Schweizer and Kelly, 2005). This category is relatively new and attracting more and more attentions nowadays (Santos, 2014; Levinson, 2012). The purpose, of said research, is to encourage students to understand the impacts of global warming on society, social culture and economy from a broader view (e.g., Crawford-Brown and LaRocca, 2006). Another purpose is to inspire students to understand the measures taken by countries to combat global warming, as well as enhance students' responsibility towards combating global warming (e.g., Santos, 2014).

Scientific mechanisms and influence factors are the focus in research that aims to study students' understanding about the concept of global warming (e.g., Varma and Linn, 2012; Visintainer and Linn, 2015；Vitale, McBride, & Linn, 2016). In some cases, comparative studies are conducted on the performances of students from different grades, gender, ethnicity, or regions (e.g., Herman, 2015). Research, which is designed from the perspectives of citizenship education and political literacy, either studies all these three aspects (e.g., Schweizer and Kelly, 2005), or focuses on the second and third aspects (e.g., Colucci-Gray, 2014). Some researchers suggest that the nature of science should be included into research contents of studies on students' understanding about the concept of global warming (e.g., Bryce and Day, 2013).

Interviews and questionnaires in previous research

Two kinds of approaches are mainly used in previous research: interviews (e.g., Visintainer and Linn, 2015; Sadler, Barab, and Scott, 2007) and questionnaires (e.g., Andersson and Wallin, 2000; Yazdanparast, et al., 2013; Sah and Bellad, 2015). Generally, clinical interview (Piaget, 1926) is adopted. The clinical method demands a high quality for researchers. On the one hand, students must feel relaxed and free without being induced or disturbed in an interview, so as to demonstrate their understanding of the concepts (Pramling, 2006). On the other hand, researchers make sure students are on the right track and the conversation is closely related to the themes of surveys (Wells, 2002). Research personnel are required to extract quickly, analyze carefully, and judge objectively to gather information from conversations and observations (Pramling, 2006). In this way, researchers grasp the essential meaning from students' words and keep interviews going successfully (Sherin, et al., 2012).

By using clinical interviews, researchers are able to deeply investigate students' true understanding about the concept of global warming (Visintainer and Linn, 2015). One-on-one interviews are time-consuming; therefore, the number of interviewees will be limited. In contrast, questionnaires are suited to large-scale survey on hundreds of students (Herman, 2015; Yazdanparast, et al., 2013; Sah and Bellad, 2015).

However, to guarantee the reliability and validity of questionnaires, researchers need a better understanding of respondents before they draw up questionnaires. Two types of items are mainly used in questionnaires: multiple-choice items, and semi-open or open constructed-response items (Shepardson, et al., 2011; White and Gunstone, 1992). To design multiple-choice items, most researchers refer to previous research by analyzing literature on students' understanding about global warming (e.g., Shepardson, et al., 2011). The frequency of each item in multiple-choice questions chosen by students reflects how students understand the concept (Herman, 2015). Constructed-response items, usually based on a real-life situation, ask students to express their opinions or attitudes in their own words (e.g., Andersson and Wallin, 2000). Keywords extracting and coding are done first, then data analysis and categorization are conducted, which concern students' understanding or attitudes towards global warming (e.g., Andersson and Wallin, 2000).

Some researchers purposively sample several students for in-depth interviews after conducting data analysis on the questionnaires' results, so as to better explain and analyze the results (e.g., Taber and Taylor, 2009; Shepardson, et al., 2011).

Students' misconceptions about global warming from previous research

According to previous studies, primary and secondary students do not understand the concept of global warming very well, and there are misconceptions that proved very difficult to change (Driver, 1983; Taber and Taylor, 2009). The results of previous research of different countries are illustrated below.

Boyes, Chuckran, and Stanisstreet (1993) survey 702 students in grades 5-10 from British and American schools. They report that 83% participants correctly perceive automobile use contributes to global warming. However, 83% incorrectly believe that there is a link between chlorofluorocarbon gases (CFCs) and global warming, and 52% incorrectly believe that global warming will be mitigated by using lead-free gasoline. According to the survey, students' misconceptions have no fundamental change as students' grade gets higher.

Andersson and Wallin (2000) survey 420 Swedish students, in which three age-levels are involved: grade 5, 9 and 12. The result shows that nearly 50% participants confuse greenhouse effect and ozone effect. Most students think heat causes global warming, but they cannot give it a scientific explanation. The survey also shows that there is no considerable change in students' misconceptions as students' grade gets higher.

Australian students in grade 6 (Taber and Taylor, 2009; Skamp, Boyes and Stanisstreet, 2007) think the following methods can be used to mitigate global warming: improving the water quality of the ocean, reducing street litter, and the use of pesticides. The confusion between general environmental issues and global warming suggests that students hold many misconceptions about global warming. For example, students believe the cause of global warming is that the holes in the ozone layer allow more energy from the sun to reach the surface of the earth. It's worth mentioning that confusion between general environmental issues and global warming is quite common among primary and secondary students in many countries (Visintainer and Linn, 2015).

There are many misconceptions about the possible causes of global warming among grade 10 students in Turkish (Kılınc, Stanisstreet, and Boyes, 2008). 82% students regard CFCs as a greenhouse gas. Over half of the students recognize that gases from rotting waste (62%) and artificial fertilizers (56%) exacerbate global warming. 61% students believe too many solar rays penetrate the atmosphere, while 67% students think ozone holes allow solar radiation to penetrate. Diseases such as cardiac problems, fish poisoning, unsafe drinking water, and food poisoning are associated as the consequences of global warming by 56% students, 57% students, 64% students, and 64% students respectively. However, the most common misconception is that 81% students hold that global warming will cause an increase in the prevalence of skin cancer. Students obtain their information about global warming from the following sources: school (39%), TV (24%), newspaper (17%), the Internet (14%), and radio (3%).

Yazdanparast, et al. (2013) survey 1035 Iranian high-school students' understanding about global warming. They find that only 5.1% of participants explain greenhouse effect correctly and completely. 71.2% and 65.9% respectively believe "incidence of more skin cancers" and "more poisonings of fish" are the consequences of global warming. 68.8% and 66% respectively think "presence of ozone holes" and "too many rays" are the causes of greenhouse effect. 67.3% and 50.9% respectively believe "use unleaded petrol" and "use fewer nuclear bombs" are cures for global warming. Participants obtain the information of global

warming from the following sources: TV (24.65%), the Internet (14.88%), school (38.49%), newspapers and magazines (14.76%), and radio (9.66%).

Among 400 students, in grades 8-10, from South India, 22.75% students know nothing about the causes of global warming (Sah and Bellad, 2015). 71.25% students think burning of coals and mines are the main cause of greenhouse-gas emission, and 6% students think greenhouse-gas emission is caused by other reasons, such as intensive farming and use of fossil fuels. 83.75% students think global warming will cause cardiovascular and respiratory disease. School (57.34%) is the major source of information regarding global warming followed by the media (36.57%) and friends and family (6.09%). Apart from that, it should be emphasized that there is a significant difference in the level of knowledge and attitude of student towards global warming according to their age, gender, grade, different medium of school and socio-economic status at $p<0.05$ respectively. No significant difference is found with religion and place of residence with respect to students' level of knowledge and attitude towards global warming.

RESEARCH QUESTIONS

This study focused on the following three questions: (1) students' understanding about the concept of global warming, including its phenomena, causes, damages, and how to mitigate global warming; (2) students' understanding about daily energy and its usage; (3) students' information sources about global warming. In addition, the interview results of three questions were made t-test and correlation analysis with students' school category, academic achievements and gender.

Method

Students' understanding of scientific concepts is closely related to their daily life, surroundings, socioeconomic and cultural backgrounds, etc. (Amin, Smith, and Wiser, 2014). It cannot be simply regarded that foreign students' understanding about global warming is the same as that of Chinese students. Hence, this study, as the initial research on Chinese students' understanding about global warming, adopted the clinical interview in the survey.

We investigated curriculum standards of science education and current textbooks in Mainland China, and selected grade eight students as the study object. An interview protocol was designed carefully beforehand (e.g., Visintainer and Linn, 2015; JR, Novak and Gowin, 1988). The theory of phenomenography (Marton, 1981) was used to create a real-life situation for students in which they would analyze, evaluate, and judge as "outsiders", so as to "prevent students from saying what others want they to say, instead of saying what they really want to say" (Colucci-Gray, 2014).

The protocol was first validated by three science teachers with "Special Rank Teacher" title in secondary school. Then it was tested by pilot interviewing fifteen, grade eight students ($\alpha= 0.77$). Finally, it was checked by data analysis and amendment. The final version included

four parts with twenty questions (see Appendix). The interview concentrated on the causes of global warming, the harms from and the cures for global warming. Students' information sources were also investigated in every single step. The clinical interview was carried out in a one-on-one way and was audio recorded. It took 15-20 minutes to interview each student.

Participants

Clinical interviews are time-consuming (White and Gunstone, 1992). Before the interview, researchers need to know some basic information about interviewees, including their schools, classes and family. During the interview, researchers have in-depth conversations with the participants face to face. After the interview, researchers collect the results and conduct analytical work. Usually, researchers themselves will have a direct impact on the process and the results of the interview (Dong Qi, 2004). As a pioneering study on students' conceptual understanding of global warming in primary and secondary school of Mainland China, this research did not carry out in the way that multiple researchers conducted clinical interviews to all the grade eight students across the country. Instead, it selected over 30 grade eight students in developed areas and let them interviewed by the researcher face to face so as to ensure the reliability, validity and feasibility of the study.

Students in grade eight from Zhejiang Province were selected as study object. Zhejiang Province is one of the economically, culturally and educationally advanced provinces in Mainland China (Zhejiang Provincial Government, 2015). Also, Zhejiang is the only province in Mainland China where an integrated science curriculum is carried out in secondary schools across the whole province (Guo, 2002). Since integrated science curriculum reform in secondary schools started in 1993, it not only promoted the teaching reform of science education in primary and secondary school, but also enhanced the quality of science education and fostered science teachers' professional development in primary and secondary schools in Zhejiang Province (Yu, 2011). Although the students didn't study the concept of global warming directly, they have studied some concepts related to global warming in science classes, including air and its components, weather and climate, energy and its usage, human being and environment, and environmental protection (MOE of China, 2011).

Multi-stage sampling was used in this study. First, Wenzhou, a city in Zhejiang Province, was selected. The education quality and level of Wenzhou was above the average in Zhejiang Province (http://www.wzer.net/view/35483.htm). Second, ten schools from Wenzhou as convenience samples were involved, including 4 in urban areas and 6 in rural areas. One to two classes were randomly selected from each school. Third, students in each class were divided into three groups according to their total score in the summative assessment of last semester, including the top group, middle group and the last group. One student was randomly selected from each group in each class and coded with "good", "common" and "poor" respectively in academic achievements. A total of 39 students were selected and finally 37 of them were interviewed. Therefore, the total amount of convenience samples was 37 (see **Table 1**). All these sampled schools were neither model schools nor low-performing schools named

Table 1. Participant demographics

School Category		Academic Achievements			Total
		good	**common**	**poor**	
urban	male	1	5	0	**6**
	female	3	1	0	**4**
rural	male	6	5	4	**15**
	female	3	4	5	**12**
Total		**13**	**15**	**9**	**37**

by Zhejiang Province Department of Education (see files on http://www.zjedu.gov.cn). In other words, the education quality and level of these sampled schools were average in Wenzhou. In summary, this study assumed the academic achievements of the samples were better than the average level of grade eight students in Mainland China.

Data analysis

Qualitative analysis was first conducted, including text entry, categorizing, coding, and data inputting. Quantitative analysis, including descriptive analysis, t-test and correlation analysis, was then carried out by software of Statistical Product and Service Solutions (SPSS).

RESULTS

The Cronbach's alpha of the interview results was 0.79. The results of t-test showed there was no significant difference between the urban and rural students, also between male and female students ($P>0.05$). The interview results of participants' understanding about the concept of global warming and correlation analysis are reported below.

Causes of global warming

36 students (97.3%) gave correct descriptions of glacial melting except one student. 35 students (94.6%) also mentioned temperature rise, 11 students (29.7%) mentioned global warming, and 2 students (5.4%) mentioned the greenhouse effect. Regarding the causes of global warming, 2 students (5.4%) correctly explained that too much CO_2 influenced the reflection of sunlight. 24 students (64.9%) mentioned that gases, such as CO_2, giving out heat resulted in global warming. 10 students (27%) considered that global warming was caused by too much CO_2, which destroyed the ozone layer. 9 students (24.3%) pointed out that too much burning and heat production leaded to global warming. 13 students (35.1%) said that global warming mainly resulted from the cutting down and logging of trees. 14 students (37.8%) vaguely explained that global warming was the result of human factors. 10 students (27%) also spoke vaguely that the phenomenon was caused by environmental destruction.

Damages of global warming

Since students' understanding about global warming focused mainly on heat, their description of its harm mainly concentrated on land submerging, resulting from sea level

rising (22 students), and climate warming (8 students). Moreover, 8 students pointed out that ozone depletion influenced human beings. Students also mentioned environmental pollution (4 students), land drought and desertification (1 student), natural hazards (1 student).

Cures of global warming

As to the issue of how to mitigate global warming starting from ourselves, "less driving", "less electricity consumption" and "less coal combustion" were mentioned by 20 students. Renewable-energy use was mentioned by 9 students, other environmental protection behaviors, such as saving water, no littering and using fewer disposable chopsticks, etc. were mentioned by 8 students, and 1 student did not answer.

Energy usage

Students' knowledge of daily energy mainly concentrated on electricity (30 students) and coal (22 students). 14 students mentioned solar power, wind energy and others. 13 mentioned household water. Only 17 students understood the use of coal, natural gas and solar power correctly. 10 students considered natural gas as clean energy. 8 students thought that the usage of solar power also polluted the environment. 2 students didn't answer.

Information sources

Students gathered information about global warming, mainly from the Internet (22 students), magazines (16 students), TV (15 students) and news (14 students). Besides these sources, they learned global warming from textbooks (8 students), teachers (7 students), newspapers (6 students) and their own daily experience (6 students). Classroom, classmates and personal prediction were mentioned three times.

Correlation analysis

The interview results of the 18 questions in the protocol (see Appendix) had no correlation with participants' school category, academic achievements and gender (P>0.05). Only two questions' results had correlation with participants' school category, academic achievements and gender (see **Table 2**). For example, there was a very significant correlation (P<0.01) between school category and students' understanding about whether liquefied petroleum gas (LPG) caused global warming. More urban students thought LPG didn't cause global warming than rural students. In addition, more urban students obtained information about global warming via news than rural students (P<0.05). Moreover, the higher level of academic achievements students had, the more information they obtained from textbooks (P<0.01). Also, a significant correlation (P<0.05) existed between gender and students' information from textbooks. Girls were more inclined to get information about global warming from textbooks than boys.

Table 2. Pearson correlation

	N	Sig.(2-tailed)	Pearson Correlation
School Category:			
LPG doesn't cause global warming	37	.005	-.452**
Obtain information about global warming from news	37	.013	-.404*
Academic Achievements:			
Obtain information about global warming from textbooks	37	.006	-.442**
Gender:			
Obtain information about global warming from textbooks	37	.042	.337*

*. Correlation is significant at the 0.05 level (2-tailed);
**. Correlation is significant at the 0.01 level (2-tailed).

Hence, we can see that the participants' information sources of global warming had high correlation with participants' school category, academic achievements and gender. The participants' understanding about the daily energy LPG had high correlation with participants' school category.

SUMMARY AND DISCUSSION

This study shows that only 5.4% of participants correctly describe and explain global warming. The rest have superficial understanding and misconception about this issue. Participants also hold a narrow perspective on daily energy and its use, mainly confined to two fields: household electricity (81.1%) and coal combustion in daily life and production (59.5%). In addition, participants learn about global warming primarily through media such as the Internet, magazines, TV and news rather than through classes and textbooks.

Regarding the conceptual understanding of global warming, findings of this study are similar to the survey of Anersson and Wallin on Swedish students' understanding of global warming (2000), which shows students consider the heat contributes to the cause of global warming but cannot give a scientific explanation. However, more participants (90%) of this study connect CO_2 with global warming than previous research's (Boyes et al., 1993; Sah and Bellad, 2015; Taber and Taylor, 2009; Kılınc, Stanisstreet, and Boyes, 2008; Yazdanparast, et al., 2013). Regarding ideas about the damage of global warming, the participants of this study concern phenomena such as sea level rising and global warming, rather than more skin cancers and more poisoning of fish (Kılınc, Stanisstreet, and Boyes, 2008; Yazdanparast, et al., 2013).

Students' understanding of the causes of global warming certainly influences their knowledge of how to combat it. Less driving and reducing combustion of fuels are considered by participants of this study as primary solutions to mitigate global warming, which is the same as British, American and South Indian students (Boyes, Chuckran, and Stanisstreet, 1993; Sah and Bellad, 2015). Meanwhile, students participating in the study are similar to students from other countries who are not able to distinguish between global warming and other

environmental issues. They claim that no littering and using less disposable chopsticks can lower global warming. Findings also shows that participants in the study who have better academic achievement, and females are more inclined to pay more attention to the function of school science education and textbooks on understanding of global warming.

The findings of students' understanding about the concept of global warming reveal the effort on connecting students' learning with the real world in science education in China. Secondary school students learn CO_2 in the context of air pollution and environmental protection, instead of learning the concept in a vacuum (MOE of China, 2015). However, all science textbooks, from a subject-centered perspective, only take the air pollution and environmental protection as learning contexts rather than key concepts for students (Jing, 2015). Hence, it is difficult for students to grasp the scientific mechanisms of global warming or other environmental issues.

Participants' response to energy and its use in the study is regarded more insufficient than South India' (Sah and Bellad, 2015). 27% of participants of this study think the use of LPG does not have any impact on global warming; 54% link household electricity directly to global warming. In addition, 21.6% claim that the use of solar power and wind energy also affect global warming. Energy is one of the "big ideas" in the science curriculum in China (MOE of China, 2011). The findings of the study expose the bottleneck in science teaching in China, which is how to deepen students' understanding of scientific concepts to obtain "big ideas" instead of some isolated factual knowledge (Liu, 2012).

It is similar to Turkish and Iranian students (Kılınç, Stanisstreet, and Boyes, 2008; Yazdanparast, et al., 2013) that students in the study have access to mass media such as TV, the Internet and newspapers to obtain information about global warming. In Mainland China, verified coal reserves account for over 90% of fossil fuels (Zhang, 2011). Coal is still an irreplaceable main source of energy for the country in the 21st century (Zhang, 2011). The finding of this study reveals that the Chinese government is making efforts to guide the public know the issues of global warming. However, the Chinese government need make more efforts to instruct the public to understand and combat global warming in a more scientific and rational way (Cheng, et al., 2013).

CONCLUSIONS AND IMPLICATIONS

The conclusions of the study are drawn based on the interview results.

1. A majority of the students do not have a scientific concept of global warming. Students acknowledge the existence of global warming, but most of them do not understand its scientific mechanism. Therefore, they think superficially that a large amount of hot carbon dioxide, caused by driving, coal and electricity combustion, leads to global warming. As a result, students believe that less driving, less coal and electricity combustion are the primary solutions to mitigate global warming. It is clear that there is a lack of systematic thinking for the consequences of global

warming on the earth's ecosystem and in the development of society within countries among students.

2. Most students lack a scientific understanding of daily energy and its usage. They understand energy in a narrow and incorrect way. Most students can only talk about coal, electricity and water, which they see everyday, and consider their usage as the causes of global warming. More students in urban schools than rural schools argue that LPG has nothing to do with global warming. Others believe that renewable-energy use may result in global warming as well.

3. Schools, classroom, teachers and parents have not really played a role in assisting students in understanding global-warming. Students receive related information mainly from mass media. Students' information sources of global warming are significant correlation with students' school category and gender, very significant correlation with students' academic achievements.

These findings are supposed to spark us profound reflections on present science education in Mainland China. First, we need to reflect upon the content of science curriculum. China is one of the world's biggest greenhouse gas emitters. There is an urgent request for science education that using global warming as the key concept to integrate students' learning on the scientific concepts of atmosphere, climate, and energy and so on, to improve students' responsibility and their ability to cope with global warming (Cheng, et al., 2013; Levinson, 2012; Meehan, 2012).

Second, we need to reflect on the teaching quality of scientific concepts. Concepts like energy, atmosphere and climate are not only terms for students but are important scientific concepts in science education (Colucci-Gray, 2014; Meehan, 2012; Albe and Gombert, 2012). Students should have a deeper understanding of the denotation and connotation of these concepts, and apply these concepts in real-life situation by debating and solving practical problems related to global warming (Jakobsson, Mäkitalo, & Säljö, 2009; Vitale, McBride, and Linn, 2016; Albe and Gombert, 2012). Research has shown that students also develop reasoning skill and critical thinking in open debates (Santos, 2014) or role-playing (Chia-Li, Ting-Kuang, Chun-Yen, 2016; Sadler and Klostreman, 2009) on the socioscientific issues and anthropologic issues about global warming.

Third, what we have to reflect upon is the responsibility and action of schools in the cultivation of qualified global citizens in the 21st century (Trilling and Fadel, 2009). Emission reduction is one of the most important tasks of the Chinese government (Cheng, et al., 2013). Schools must put topics and contents about global warming in integrative practical activities, school-based curriculums, school science festivals, and home-school activities to educate students (Sadler and Klosterman, 2009; Albe and Gombert, 2012). Researching and debating the scientific mechanisms of global warming, human measures, effective solutions and government policies should be introduced to students by organizing teachers of different subjects and parents from different professional fields (Fensham, 2014). In addition, it is possible to organize students to walk out of campuses and reach communities, to contribute

to popularizing scientific knowledge among the locals to understand and combat global warming (Fensham, 2014).

Furthermore, mass media's role in transmitting knowledge of global warming needs to be enhanced. While reporting the phenomena or other related topics of global warming, mass media are supposed to combine scientific explanations and effective solutions with their introduction (Fensham, 2014). In other words, mass media should attach importance to scientificity, popularity and readability at the same time, by introducing the scientific mechanism of global warming in popular and easy-to-understand ways (Bryce and Day, 2013).

This research is an initial study to investigate students' understanding of global warming in Mainland China. Some limitations exist in research samples and contents. There are obvious differences among Chinese provinces in terms of economic, cultural and educational aspects. Future research is needed to select and interview students in the central, western and northern regions of China to get a brief nationwide view of grade eight students' understanding of global warming. Based on the results of nationwide interviews, the questionnaire for a nation-wide survey will then be designed to grasp the current situation and differences in understanding about the concept of global warming among students throughout the country.

Future research is needed to select students from different grades to investigate students' progressions in learning global warming. All the results about students' understanding of global warming provide the foundation for deepening science education reform in Mainland China, and cultivating students' high quality of scientific literacy to combat global warming worldwide.

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APPENDIX

Interview Protocol

I. Introduction: The Concept of Global Warming

1. Ecological Situation: Present pictures depicting the consequences of global warming.

    One picture shows different scenes of the Glacier National Park in 1910 and 1998. Another picture shows Mount Kilimaniaro's scenes in 1970 and 2000.

    Question 1: What do you think is happening in the pictures?

    Question 2: Can you think of anything or any phenomenon similar to what happened in the pictures?

    Question 3: Where did you learn about these things or phenomena?

2. Causes Investigation

    Question 4: What do you think caused the things that happened in the pictures?

    Question 5: How did they happen?

    Ask students about their understanding of the phenomenon by giving them some hints. Questions as follows are asked: Why does ... (the phenomenon) happen? What causes it? How does …(the phenomenon) cause global warming?

    Question 6: Are the things that happened in the pictures harmful to human beings or the earth? What is the harm?

3. Information Sources

    Question 7: Where did you learn about this (students' answer)?

II. Reasoning: Mechanisms of Global Warming

4. Natural and Anthropogenic Causes

    Question 8: Is there any other factor causing global warming?

    Students are provided with some hints during this process. Questions are asked as follows. "Some people think using a vehicle can lead to global warming. If it is true, why does it cause global warming? (theory investigation)"

5. Information Sources

    Question 9: Where did you learn about this (students' answer)?

III. Reasoning: Energy Usage

6. Elicit Ideas about Energy Usage

   Question 10: How do you use energy at home? Please give examples.

   Question 11: In what way do people use energy? Please give examples.

7. Present Some Pictures of Life Situations

   Question 12: Do you think the way that the energy is used in the pictures will cause global warming?

   Question 13: Why or Why not?

   Question 14: Are there other types of energy usage that can cause global warming?

8. Information Sources

   Question 15: Where did you learn about this (students' answer)?

IV. Advice: Lowering Energy Usage

   Question 16: What suggestions would you offer to your friends on reducing energy usage?

   Question 17: Why do you think these suggestions would reduce energy usage?

   Question 18: Do these suggestions have any impact on global warming?

   Question 19: Why or Why not?

   Question 20: Do you think it is important to reduce energy usage or save energy? Why or Why not?

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