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Enhancing Primary School Students' Knowledge about Global Warming and Environmental Attitude Using Climate Change Activities

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Climate change generally and global warming specifically have become a common feature of the daily news. Due to widespread recognition of the adverse consequences of climate change on human lives, concerted societal effort has been taken to address it (e.g. by means of the science curriculum). This study was designed to test the effect that child-centred, 5E learning cycle-based climate change activities would have *over* more traditional teacher-centred activities on Malaysian Year 5 primary students (11 years). A quasi-experimental design involving a treatment ($n = 55$) and a group representing typical teaching method ($n = 60$) was used to measure the effectiveness of these activities on (a) increasing children's knowledge about global warming; (b) changing their attitudes to be more favourable towards the environment and (c) identify the relationship between knowledge and attitude that exist in this study. Statistically significant differences in favour of the treatment group were detected for both knowledge and environmental attitudes. Non-significant relationship was identified between knowledge and attitude in this study. Interviews with randomly selected students from treatment and comparison groups further underscore these findings. Implications are discussed.

Keywords: *Climate change activities; Global warming; Attitude towards environment*

Introduction

Climate change as the result of human activity is one of the most important issues facing humanity today. According to the US Environmental Protection Agency

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(USEPA), climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer (USEPA, 2012). Global warming is one of the causes of climate change. Human economic activities are among the major contributors to the increase in the concentrations of greenhouse gases (IPCC, 2007; Malaysian Meteorology Department, 2009). Due to these tremendous changes in climate and their effects on the natural environment, all societies are facing challenges because their future generations are expected to increasingly experience adverse effects of climate change (UNEP, 2012).

Individuals need to be informed about the harmful consequences of their activities on global climate change. This means that individuals need to be knowledgeable about how their own specific activities contribute to global warming. Being knowledgeable about environmental issues tends to create a greater concern over pertinent issues and prompt society as a whole towards performing pro-environmental behaviour (Marquart-Pyatt et al., 2011). For the knowledge to significantly influence the formation of behaviour, members of society should be taught about the environment as an integral part of their everyday living and about how every action has consequences for the whole ecosystem (Karpudewan, Ismail, & Mohamed, 2009). This is especially important for emerging economies, including Malaysia, where rampant (illegal) logging and other practices continue to increase the levels of environmental degradation. In neighbouring Thailand, for instance, it has been recorded that Bangkok has decreased electricity usage by 73.34 MW equivalent to 41.6 tonnes of carbon dioxide following the Earth Hour campaign (CBC, 2008).

Besides knowledge, the attitude about some subject also influences associated behaviours directly (Karpudewan, Ismail, & Roth, 2012; Kuhlemeier, van den Bergh, & Lagerweij 1999; Stern, 2000). Knowledge and attitude collectively are recognised as human factors that have considerable effects on the achievement of a safe environment (Ibrahim & Babayemi, 2010). It is important to increase individual knowledge and attitudes on issues concerning the environment to develop environmentally responsible and sustainable behaviours. Developing environmental awareness and supporting positive attitudes towards the environment beginning from the primary school level may help to foster environmentally literate citizens and to build sustainable future (Bas, Teksoz, & Ertepinar, 2011). Claims concerning the existence and the strength of relationship between knowledge and attitude are not consistent, however. For instance, students' attitudes towards science and their understanding of the subject were perceived as moderately related (Shrigley, 1990; Weinburgh, 1995). Various other studies indicate the existence of strong and significant relationships between these variables, namely strong relationship is evident in studies of students' attitudes towards science and their understanding of the subject (Dhindsa & Chung, 2003; Osborne, Simon, & Collins, 2003; Simpson & Oliver, 1990). Similar strong relationship was also reported between attitude towards the environment and environmental knowledge in designing environmental policy (Arcury, 1990). There is substantial evidence for the existence of positive links between environmental knowledge and formation of positive

environmental attitude (Barraza & Walford, 2002; Tikka, Kuitunen, & Tynys, 2000). Collectively, environmental attitude and knowledge influence the formation of environmental behaviour as shown in a meta-analysis of 128 pro-environmental behaviour research studies ruled out that knowledge and attitude as two variables that influence formation of pro-environmental behaviour (Hines, Hungerford, & Tomera, 1986). In a model of ecological behaviour, environmental knowledge and attitude were identified among the five variables that determine pro-environmental behaviour (Fietkau & Kessel, 1981). A model of pro-environmental behaviour (see Kollmuss & Agyeman, 2002) was proposed as an effort to bridge the gap between environmental knowledge and pro-environmental behaviour. In this model, knowledge and attitude act as internal factors that influence formation of pro-environmental behaviour.

Environmental knowledge and attitudes have been extensively researched among adults. More recently, studies focused on environmental knowledge and attitudes involving children (Pauw & Petegem, 2011) following the suggestion that young children may serve as effective agents to promote environmental responsibility (Leeming, Dwyer, Porter, & Cobern, 1997). In a study involving Lebanese students both girls and boys held favourable attitudes towards the environment but lacked in their environmental knowledge (Makki, Abd-El-Khalick, & Boujaoude, 2003). In Singapore, ninth-grade students' levels of environmental knowledge were low and these students had moderate positive environmental attitude (Tan, Eng Lee, & Chuan, 1998). A study of environmental knowledge and attitude among Canadian and Taiwanese fifth-grade students showed that children from both countries expressed positive attitudes towards the environment and moderate level of knowledge (Huang & Yore, 2005). Turkish children's level of knowledge was identified to be below a satisfactory level but they expressed favourable attitudes towards the environment (Alp, Ertepinar, Tekkaya, & Yilmaz, 2006). The analysis of 163 11-year-old Malaysian primary school students' level of environmental knowledge revealed that the students possessed commendable levels of knowledge (Aini, Nor Azura, & Fakhru'l-Razi, 2011). A separate study involving 348 Malaysian primary school students reported that the students environmental attitude slightly above average (Karpudewan & Chin, 2013). Other studies report limited knowledge about climate change and global warming (Shepardson, Niyogi, Roychoudhury, & Hirsch, 2012; Taber & Taylor, 2009).

School-based education specifically plays an important role in improving students' attitude and knowledge and it was indicated that potential effectiveness of education is higher when students possesses knowledge and positive attitude towards a specific issues particularly issues concerning global warming (Barraza & Walford, 2002; Boyes & Stanisstreet, 2012). The imperative role of education is evident in various studies that have employed appropriate pedagogical approaches to improve students' knowledge and attitudes. This is evident from investigations that used green chemistry curriculum to improve pre-service teachers' environmental attitude and knowledge (Karpudewan et al., 2012; Karpudewan, Roth, & Ismail, 2013).

Pedagogical Approaches Used to Teach Climate Change

Previous studies indicate that knowledge and attitude towards specific environmental concern may be improved using student-appropriate instructional strategies. At the elementary level, students need to develop an understanding of basic concepts that underlie weather and climate change (Lambert, Lindgren, & Bleicher, 2012). To cater to the needs of the elementary students, the relevant science concepts (e.g. carbon cycle, greenhouse effect or water cycle) were taught using inquiry-based approach. Rather than simply presenting the concepts, inquiry-based interactive visualisation was used to teach middle-school students about global climate change (Svihla & Linn, 2012). In another study, a socio-constructivist and experiential teaching process were used (Pruneau, Gravel, Bourque, & Langis, 2003). Active instructional strategies also resulted in significantly improving students' understanding about climate change (Porter, Weaver, & Raptis, 2012). Besides improving the acquisition of knowledge, various attempts have been made to remediate students' misconceptions about climate change using Science Technology and Society global warming instruction (Rye, Rubba, & Wiesenmayer, 1997) and constructivist-based climate change activities (Karpudewan, Roth, & Chandrakesan, 2014).

The aforementioned studies suggest that active learning approaches provide better opportunities for learning than teacher directed, lecture-based approaches. Constructivist approaches improve students' conceptual understanding concerning global warming and greenhouse effects; and inquiry-based approaches supplemented with direct instruction effectively improve students' understanding of ozone layer depletion and the greenhouse effect. It was suggested that besides improving cognitive ability, effective instructional strategies also should lead to improved attitudes. Among the existing constructivist approaches, 5E learning instruction stands out because it enhances students understanding of scientific concepts and other affective components such as attitude, interest and motivation towards science subject and learning of sciences.

5E Learning Cycle

The 5E instructional model was developed in the late 1980s as a component of the Science for Life and Living curriculum created through the Biological Sciences Curriculum Study (Bybee & Landes, 1990). The 5E learning emerged from the expansion of the learning cycle (exploration, invention and discovery) (Atkin & Karplus, 1962). It is a systematic approach for teaching scientific inquiry with a constructivist foundation involving five phases: engagement, exploration, explanation, elaboration and evaluation (Bybee & Landes, 1988; Bybee et al., 2006: Eisenkraft, 2003). During the *engagement phase*, the teacher sets the stage by introducing the students with the concept of the greenhouse effect. In the *exploration phase*, students conduct hands-on tasks such as testing a hypothesis about the greenhouse effect. They collect evidence and data, record and organise information, and work in collaborative groups. In the *explanation phase*, students discuss the information collected from the experiment. The teacher

guides students in drawing conclusions from their findings. During the *elaboration phase*, the teacher assists students in developing an understanding of the concepts by extending and applying the evidence to real-world situations outside the classroom. During the *evaluation phase*, the teacher assists students in summarising the relationships between the variables studied; and he poses higher-order questions that help them make judgements, analyse data and evaluate their work. The 5E learning cycle is a widely adopted hands-on, inquiry-based scientific pedagogy that effectively improves students' understanding (Bybee & Landes, 1988; Bybee et al., 2006; Stamp & O'Brian, 2005).

5E activities have been developed and integrated into teaching and learning of the circulatory system for primary level and resulted in removing misconceptions and improved understanding (Cardak, Dikmenli, & Saritas, 2008). Seyhan and Morgil (2007) employed a constructivist 5E learning approach to teach acids and bases to one group of chemistry students and observed improved understanding and attitude towards learning chemistry. Two studies investigated the effectiveness of the 5E learning model towards improving student understanding of force and motion, both showing positive outcomes (Campbell, 2006; Yildiz-Feyzioglu & Ergin, 2012). Another study investigated the effect of 5E learning on mental ability with respect to the relationships between scientific concepts of the elementary students (Bilgin, Coskun, & Aktas, 2013) and documented positive outcomes as well. In addition to knowledge, each phase has a specific function and contributes to the teachers' coherent instruction and to the learners' formulation of better attitudes (Bybee et al., 2006). It is evident that the learning cycle approach can result in improved attitudes towards science and science learning (Lawson, Abraham, & Renner, 1989). For instance, the integration of an expanded 7E learning cycle—engage $\rightarrow$ elicit + engage; and evaluate $\rightarrow$ evaluate + extend—improved attitudes towards learning chemistry (Siribunnam & Tayraukham, 2009) and physics (Soomro, Qaisrani, & Uqaili, 2011) when compared to a traditional method of expository teaching.

To our knowledge, efforts that employed 5E learning cycle approach to improve environmental knowledge, specifically knowledge about climate change and greenhouses as well studies using 5E approach to improve pro-environmental attitude literature is lacking in the literature. Specifically, in the context of Malaysia, education is very teacher-centered and exam oriented. Hence, the teachers stringently follow conventional teaching methods suggested in the curriculum guides and expository teaching. Hence, the present study was designed to investigate the differential impact of specially designed, 5E learning cycle-based activities on primary children's knowledge and environmental attitudes. In the quasi-experimental part of the study, three hypotheses were tested:

(a) Specially designed student-centred, 5E learning cycle-based climate change activities increases climate change knowledge of the students compared to the traditional teacher-centred approach.
(b) Specially designed, 5E learning cycle-based student-centred climate change activities increases pro-environmental attitudes of the students compared to the traditional teacher-centred approach.

(c) There is a significant positive relationship between pro-environmental attitudes of the students from treatment group with their knowledge about climate change based on the post-test results.

Similar to other studies in the literature—for exmple, Leeming et al. (1997), who measured the effect of The Caretaker Classroom Program on environmental knowledge and attitude of elementary student, and Pauw and Petegem (2011), who has measured the effect of Flemish eco-school programme on students environmental knowledge and attitude—the purpose of the present study is to identify the effect of an intervention (here the 5E approach) on knowledge about global warming, pro-environmental attitudes of primary school students and the relationship that exists between knowledge and attitude. Both knowledge and attitude were considered in this study because these are conditions for achieving internalised pro-environmental behaviour and a positive relationship between attitude and knowledge is important in promoting the behaviour (Stern, Dietz, Kalof, & Guagnano, 1995).

Research Methods

This study was designed in the context of primary school education in Malaysia with the underlying purpose of selecting teaching models that promote students' knowledge related to global warming and attitudes towards the environment. Integrating climate change activities into teaching and learning primary science reflects an initial effort to make the learning relevant to students' everyday lives. A quasi-experimental research design involving treatment and comparison groups with pretest as covariate (Shadish, Cook, & Campbell, 2002) was used to test two hypotheses: students taught using 5E learning cycle-based climate change activities and students taught according to the traditional curriculum in Malaysia do differ in understanding, attitude and significant relationship exist between understanding and attitude. Qualitative interviews were conducted with randomly selected students to deepen our understanding of students' knowledge and attitude after the experiment.

The quasi-experimental design was used in this study for inferential purposes because the leading methodologists in the field claim that this is the most appropriate design to investigate effectiveness of an intervention in intact settings (Shadish et al., 2002). In the quasi-experimental approach, whole classes are randomly assigned to treatment and comparison conditions. This approach has been used by other studies investigating, for example, educational sustainability programmes focusing on sustainable consumer behaviour (Frohlich, Sellmann, & Bogner, 2013) or the ecological footprint in development of ecological behaviours (Gottlieba, Vigoda-Gadota, & Haim, 2013). It is generally recognised that there are potential weaknesses in employing such designs, such as possible cross-contamination when treatment and comparison classes are from the same school or the possibilities for other factors causing differences when the classes are from different schools with culturally, socio-economically or racially different student profiles (selection bias). When there is only one teacher involved in each condition (treatment 5E; comparison, teacher-centred),

then teacher effects are nested within treatment making it difficult to untangle the impact of the teacher from that of the curriculum. Because there are different schools involved, other nested effects may lead to treatment-outcome interactions that cannot be untangled with this quasi-experimental design, which therefore constitute the limitations for attributing causes to the 5E curriculum.

Research Participants

The sample for this study consisted of 115 Year 5 students (11 years of age) from 2 primary schools in a metropolitan area of Malaysia. For the purpose of the study, two participating Year 5 classes, one each from School A and School B were randomly assigned to treatment and comparison condition. The treatment group consisted of 55 students from School A and the encompassing theme of energy was taught using 5E learning cycle-based climate change activities. The comparison group consisted of 60 students from School B and the theme of energy was taught in a conventional, teacher-centred manner. In the quasi-experimental approach using a pretest as covariate, the analysis of covariance (ANCOVA) provides direct estimates of treatment differences even if the groups are different prior to the study as long as the condition of equality of regression slopes is met (Shadish et al., 2002). In other words, the covariate 'provides an adjustment for initial differences between the groups' (Cook & Campbell, 1979, p. 153). (Tests of difference on the pretest measure would constitute redundant information and increase the overall probability of type I errors.)

To minimise the possibility of selection differences (Shadish et al., 2002), we selected schools and teachers matched on many parameters. Both schools are fully governmentally funded co-educational suburban schools from the same district in the state of Perak (West Malaysia), with more or less the same number of students and teachers. In both schools, the generally middle-class student population consists predominately of Malays, followed by Chinese, Indian and others. Both schools have basic amenities such as computer and science labs. The socio-cultural status of the students and the living standards of the families, parents' educational backgrounds, socio-economic status of the families and their social lives are very similar. This is evident from a survey performed with the students from both treatment and comparison groups. In this survey, students were requested to indicate their parents' income, education level of father and mother, and number of siblings.

The science lessons were taught by the students' regular science teachers. A female teacher with 10 years of teaching experiences taught the comparison group whereas a female teacher with 9 years of teaching experiences taught the treatment group. Both teachers received their early training at the same teacher training institution. During their in-service courses, the Ministry of Education identified both teachers as experts in terms of subject matter (content knowledge) and pedagogical knowledge. The teacher of the treatment group was provided with a manual containing the climate change activities. Additionally, during the intervention, the first and third authors were present to assist the teacher in case any problem arises in terms of implementing

the activities. However, throughout the five activities the teacher required no assistance to conduct the activities as intended. The teachers were provided with lesson plans and strictly advised to follow these. The teachers' behaviours during the teaching and learning process were observed by the first and third authors to make sure the consistency in their teaching and the planning of the lessons (as in lesson plans) was strictly followed.

Treatment and Comparison Curriculum

Students in the treatment and comparison groups learned about climate change in the context of the official curriculum on energy, which lasted five weeks in both groups. The central differences between the two groups consisted in the student-centred, 5E approach in the treatment group and the heavily teacher-centred approach in the comparison group. Thus, for example, the students in the treatment group engaged in 5E learning cycle laboratory activities, where they actively discussed their findings. Subsequently, the groups reported back to the whole class, where the teacher tended to probe the student presenters in greater depth and provided suggestions for further consideration and study. The 5E learning cycle climate change activities involved (a) investigating the effect of greenhouse gases, (b) the carbon dioxide role play, (c) modelling the melting of icebergs, (d) modelling the melting of glaciers and (e) investigation of renewable and non-renewable energy that students use in their homes. These activities were adapted from resource packages such as the Climate Change Education Package, Air Watch Programme (Department of Environment and Conservation, 2013) and from the *Green Teacher* magazine (*Green Teacher*, 2003) and integrated into the lessons on energy.

In the comparison group, the teacher followed the regular textbook. She mainly lectured interacting little with students. When she asked questions, there tended to be few responses so that the teacher most frequently answered her own questions before going on. The teacher used activities suggested from the official syllabus to deliver the topic of energy (Curriculum Development Centre, 2006). Students generally were referred to their textbook and tended to complete a workbook. In Table 1, contrasting observations in treatment and comparison group are provided for the five topics that constituted the climate change curriculum. Prior to the implementation of the study, both the teachers were given a briefing about the activities and the lesson plans that the researchers had prepared for each lesson. Both teachers were advised to follow the planning as strictly as possible for the purpose of limiting differential teacher effects on the treatment. (Detailed lesson plans for both groups may be obtained from the first author.) Throughout the study, the first and third authors observed all the lessons in both groups. This was (a) to ascertain that the treatment groups were indeed taught equivalent concepts (b) to observe the students engagement and (c) to ensure the lessons were taught according to the lesson plans.

Climate change activities in this study refer to the activities that have been integrated in primary science learning in relation to the topic of energy (Department of

Table 1. Observations: in the treatment and comparison group

Treatment	Comparison
Activity 1: After completing this lesson the students should be able to illustrate the effect of greenhouse gases	
The teacher set the stage of learning by introducing the students the concept of greenhouse effect. Teacher shows PowerPoint slides of how the greenhouse effect occurred and the greenhouse gases involved. Teacher also asked questions to stimulate students' inquiry regarding the topic. Students then worked in small groups and prepared a mini greenhouse using the materials provided by the teacher and measured the change in the temperature in the greenhouse that they have developed. Students identified various types of greenhouse gases and the effect of these gases in trapping the heat	The teacher roughly sketches the diagram that shows greenhouse effect on the whiteboard. Students started to copy the diagram in their exercise book. The teacher continued her drawing and labelled the diagram accordingly. Students followed as well. After complete the drawing and labelling the teacher started to describe the effect of the greenhouse gas: the greenhouse trapped the heat from the sun. At this time students listen to the teacher's illustration. After that the students were given 10 minutes to answer the questions in the workbook. After 10 minutes the teacher called the students' name to read out their answer and the teacher dictated the right answer. The students copied the right answer given by the teacher
Activity 2: After completing this lesson the students should able to identify and list all the greenhouse gases	
Students played the carbon dioxide game, which is a simulation game that illustrated how carbon dioxide in the atmosphere trapped the heat from the sunlight (*Green Teacher*, 2003). In this game, the students assumed the roles of carbon dioxide molecules, the sunbeam, the earth and the atmosphere. This role-play session was expected to allow students to understand that carbon dioxide molecule will trap the heat. Based on the information provided in the flash card (one student will be appointed to read the information in the flash card) the number of carbon dioxide molecules in the atmosphere will be moderated. Information such human activities that could reduce (e.g. recycle, ride bikes and plant trees) or increase (e.g. drive more cars, cut down trees and burn rubbish) the amount of carbon dioxide molecules were included in the card	The teacher used a textbook and a reference book to note all the gases listed on the whiteboard. She asked the students to read aloud all the gases one by one. There was then a lot of teacher–student interaction. For example, the teacher called on one student and asked 'What is the effect of greenhouse?' That student stand up and looking at the teacher and could not answer. The teacher posed the question again and this time to the whole class, 'Ok class anyone of you can answer?' No one responded to the teacher's question. The teacher continued, 'Since no one answering I will explain again.' The teacher explained the whole effect of greenhouse gases again. She then continued to lecture about how gases are released from some of our daily activities such as open burning, emission from the vehicles

(*Continued*)

Table 1. Continued

Treatment	Comparison
Activity 3: The objective of the third activity (melting of icebergs) is to impart the knowledge that greenhouse gasses which has contributed towards global warming (from the previous lessons) resulted in the melting of the icebergs at the Arctic and Antarctic, which consequently increased the sea level	
The students do a hands-on activity that reflects the situation at the Arctic and Antarctic. Students depict the situation of the Arctic and Antarctic. The students worked in a group of three and filled a beaker with water and measured the volume of the water. A large ice cube was immersed into the beaker with water. The teacher asked the students to observe what happens to the ice cube and the volume of the water. The students were requested to measure the final volume of the water after all the ice melted. They were asked to compare the final volume with the initial volume. In their working groups, students prepared illustration of Arctic and Antarctic and presented their work to the class. With the teacher's assistance the students described how increasing global temperature could cause the melting of the ice	In this lesson, the teacher-centered approach continued. Following questions, the teacher tended to pause for a while and, since students rarely responded, the teacher continued by providing answers to her own questions or by lecturing new facts. Referring to her notes, the teacher continued listing the causes of global warming on the white board. After listing the points on white board she asked the students to copy them in their exercise book
Activity 4: Students are to come to understand the effects of the melting of glaciers on global water levels	
Students do the hands-on activity 'Melting of Glaciers'. Similar to the activity on melting of icebergs, the hands-on activity was employed for students to get a real experience of how the melting of ice. For the purpose of this activity, students worked in groups. They were asked to place a large ice cube on a slanted board. The board allowed the melting water to run into the beaker. Students measured the height of the water and left the plank and beaker under the sunlight. The height of the water in the beaker was measured every 10 minutes until the ice cube was completely melted. Students subsequently discussed the results in their groups and then presented the outcome to the rest of the class. The teacher interviewed the presenters at times with questions and suggestions	The lesson was conducted in teacher-centered fashion. She started to talk about glaciers and icebergs that can be found at Arctic and Antarctic. The teacher showed pictures of an iceberg and a glacier to illustrate the melting of ice. Afterwards, she asked students to answer the questions in the workbook and discussed the answers with them

Activity 5: Learning about renewable energy and its effect on global warming Students were introduced the types of renewable energy and non-renewable energy and the contributions of renewable energy to global warming. Students then discussed the topic in small groups to identify ways of reducing energy consumptions in their home and they were also asked to design their own energy efficient house using renewable energy and minimal non-renewable energy resources. Students were requested to solve the problem faced by the local energy board of meeting the increasing demand for energy in the students' local area	The teacher began by reviewing the previous lesson. Then she suggested the use of renewable energy as a way of reducing the human impact on global warming. The teacher listed examples of renewable and non-renewable energy. She talked in detail about the sources of the energy and differences between these two categories of energy. She described why it is important for us to non-renewable. Besides opting to use renewable energy we also should save energy. For example, switch off the lights when you are not using, do not leave computers idle. The teacher continued listing various other energy saving behaviours. After completing her teaching she asked the students to answer the questions in the workbook and discussed the answers

Environment and Conservation, 2013; *Green Teacher*, 2003). Both the greenhouse effect and global warming are fundamental to understanding global climate change (Lambert et al., 2012). Therefore, climate change activities in this study focused on issues and problems associated with global warming and the increase in the greenhouse effect. These issues were presented in the form of hands-on activities related to the greenhouse effect, renewable and non-renewable energy, carbon dioxide, melting sea ice and melting glaciers.

The climate change activities in this study were developed based on the 5E learning cycle: engagement, exploration, explanation, elaboration and evaluation. Fundamentally, the 5E learning cycle is grounded in constructivist theory that focuses on enhancing the learners' ability to develop new knowledge by using an active inquiry approach (Budprom, Suksringam, & Singsriwo, 2010). Consistent with a constructivist perspective, the 5E learning cycle model describes the process of learning in five stages (Llewellyn, 2005).

During the *engagement phase*, the teacher sets the stage by introducing the students to the concept of the greenhouse effect. In the *exploration phase*, students conduct hands-on tasks such as testing a hypothesis about the greenhouse effect. They collect evidence and data, record and organise information, share observations, and work in collaborative groups. In the *explanation phase*, students discuss the information collected from the experiment. The teacher guides students in drawing conclusions from their findings. During the *elaboration phase*, the teacher assists students in developing an understanding of the concepts by extending and applying the evidence to real-world situations outside the classroom. During the *evaluation phase*, the teacher assists students in summarising the relationships between the variables studied; and she poses higher-order questions that help students to make judgements, analyse data and evaluate their own work.

Instruments

Knowledge of global warming. A true/false knowledge-based test was adapted from a study conducted in the UK (Taber & Taylor, 2009) to examine primary students' knowledge of global warming before and after the climate change activities. This instrument consists of 20 items that evaluate the students' knowledge of the effect of global warming on climate change and the effect of climate change on the natural environment. The test was translated into the Malay language. A language expert ascertained that the Malay translation is consistent with the English version and that it is appropriate for students at the age level. The original test was reported to have high validity and reliability (Taber & Taylor, 2009). We conducted a pilot study to ascertain the reliability and validity of the Malay translation. An experienced primary school science teacher and a senior lecturer in science education at our university validated the content of the questions. Thirty children participated in determining the consistency of the instrument. The obtained Kuder–Richardson coefficient of $KR20 = 0.83$ suggests high internal consistency.

Attitude towards the environment. To examine the attitude towards the environment among primary schools students, the *New Environmental Paradigm Scale for Children* (NEP Scale for Children) was used (Manoli, Johnson, & Dunlap, 2007). This scale measures environmental worldview and consists of 10 items instead of the 15 items for the original NEP scale (Dunlap, Van Liere, Mertig, & Jones, 2000). The items are rated on a 5-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The NEP Scale for Children tends to exhibit high internal consistency values (Petegem & Blieck, 2006; Wu, 2012). For the purpose of this study, the questionnaire was translated into the Malay language (*Bahasa Malaysia*). The pilot study showed that the Malay version of the NEP Scale for Children also has high internal consistency (Cronbach $\alpha = .85$). In this study, the NEP for Children questionnaire was presented as single factor measure (Amburgye & Thoman, 2012) rather than the three-factor measure that it has been in the original version (Manoli et al., 2007).

Interviews

Interviews were conducted to obtain further insights of students' knowledge about global warming, attitudes towards the environment, and (in the treatment group) their views about the climate change activities. For this purpose, 30-minute semi-structured interviews were conducted individually with five students each from the treatment and comparison groups. The sample size of 10 students participated in the interviews is considered sufficient given the assertion that an appropriate sample size for a qualitative interview that adequately answers the research question and for simple questions might be in 'single figures' (Marshall, 1996). Following Marshall's recommendation 10 students were interviewed in this study. The same students were involved in the pre-treatment and post-treatment interviews. A purposive sampling strategy was employed to select the participants for the interviews based on the criteria of (a) willingness to participate and (b) willingness to express themselves. The third author conducted both sets of interviews. The initial interviews were conducted during the week before the treatment began; the second set of interviews was conducted two weeks after the treatment was completed. The interview questions (appendix) to assess students' understanding included: What is global warming? What do you understand about global warming? What is the cause for global warming? If we had a way of making sure that there was no rubbish in rivers, is that going to help reduce global warming? Explain how we combat global warming by making sure the rivers are clean? The purpose of this question is to identify whether students are competent to indicate the cause of global warming correctly. We can rule out whether students will be linking river pollution and global warming and why they think both river pollution and global warming might be connected. To assess their attitudes towards the environment, students were asked about the frequency with which they turn off the air conditioning or other electrical appliances when not in use. To identify their views about climate change activities, they were asked questions such as 'Which activity helped you to better understand about global warming?'

Results

This study involved a mixed-method approach, including a quasi-experimental quantitative part with pre- and (qualitative) post-test interviews conducted to probe students' knowledge and environmental attitudes. The quasi-experimental approach that uses a pretest to comparison possible pre-treatment differences is the method of choice for testing treatments in field settings where complete random assignment and the use of no-treatment control groups are impossible for institutional reasons (Shadish et al., 2002).

Quantitative Analysis

To rule out some of the possible hypotheses that arise for quasi-experimental studies, an ANCOVA approach was used (Shadish et al., 2002) where the pretest comparison within-group variance based on pre-experiment differences. This analysis requires a test that the null hypothesis of equality of regression slopes within the treatment and comparison groups is not violated to guarantee that the ANCOVA approach to provide meaningful results (Kirk, 2013). To control experiment-wise error rates (i.e. error rates for the study as a whole), Bonferroni adjustments were used to test each hypothesis at the corresponding $\alpha_{adj} = \alpha_{exp}/3$ levels (i.e. $\alpha_{adj} = .0167, .0033, .00033$). The first hypothesis stated that there would be no significant difference in understanding about global warming between treatment and comparison treatment groups as measured by global warming test. This hypothesis was (as presented in Table 2) rejected ($F(1, 112) = 193.6$, $p < .00033$). The treatment group ($M_{exp} = 17.07$, $SD_{exp} = 2.54$) outperformed the comparison group ($M_{cont} = 9.50$, $SD_{cont} = 2.75$), suggesting that they were more knowledgeable about global warming. A total of 15.6% (effect size $\eta = 0.156$) of the total variance in the post-test scores was accounted for by the group differences while controlling for the effect of the students' pretest scores.

The second hypothesis stated that there would be no significant difference between treatment and comparison groups in the attitude towards the environment as measured by the *NEP Scale for Children*. This hypothesis (as presented in Table 2) was rejected ($F(1, 112) = 7.52$, $p < .0167$). The treatment group exhibited more pro-environmental attitudes ($M_{exp} = 35.27$, $SD_{exp} = 4.66$) than the comparison group ($M_{cont} = 32.9$, $SD_{cont} = 4.29$), suggesting that some or all aspects of the treatment brought about a change in attitude, which became more positive than that in the

Table 2. Quantitative results

	Treatment		Comparison				
	Mean	SD	Mean	SD	*F*	Effect size	Decision with respect to *H*
Understanding	17.07	2.54	9.50	2.75	193.6	0.156	Reject
Attitude	35.27	4.66	32.9	4.29	7.52	0.006	Reject

comparison group. About 6% (effect size $\eta = 0.06$) of the total variance in the post-test scores was accounted for by the group differences controlling for the effect of the students' pretest scores.

The third hypothesis states that there would be no significant correlation between pro-environmental attitude and knowledge about global warming of the treatment group students based on the post-test results. This null hypothesis was not rejected at the chosen α-levels ($r(53) = 0.285$; $p = .035$) suggesting that there was no significant correlation between understanding about global warming and pro-environmental attitude.

Qualitative Analysis: Understanding about Global Warming

The interviews with selected students from the treatment and comparison groups substantiated the quantitative results and deepened our understanding of the facets of knowledge and attitudes. Prior to the study, students were asked to provide responses to the question, 'What is global warming?' Their answers were brief, and in many instances students indicated that they had not heard about the topic. This is consistent with the observation that prior to instruction, students' knowledge about the topic was minimal in both groups. The brief responses also hindered the interviewer to proceed with further questions to gauge any understanding.

The same question was posed to the students from comparison and treatment groups after the treatment. The students in the comparison group declared little knowledge about the curriculum despite the five-week exposure to it in the lecture format. For example, Su said 'I think teacher has mentioned about it but I don't remember lah.' Other responses included 'Never heard about it' (Adib), 'I think I heard about it but I don't have clear idea' (Shae) and 'I don't know lah ... the teacher have mentioned in the science lesson' (Siti). The short responses obtained from the comparison groups prevented the interviewer to conduct deeper probes by means of the remainder of the prepared questions. The majority of the students had heard about global warming and climate change. However, they did not describe the phenomenon in any detail. Therefore, in the following session only the interview responses of the treatment group are discussed.

The students in the treatment group provided brief, but specific and knowledgeable responses. For example, in response to the question 'What do you understand about global warming?' students made statements such as 'Global warming is the increase of global temperature. The hot climate is due to global warming' (Adi), 'I think it is because the increase of temperature. The hot climate ... less rain and dry outside there' (Ali) and 'maybe about the climate now is too hot ... like how we are experiencing now' (Amar).

In their responses students tended to link global warming to the increases temperature and hotter weather. A more sophisticated understanding of global warming is reflected in the students' statements that they are *actually* experiencing the phenomena in their real life, which they also supported with examples from their everyday life. When asked about the causes for global warming, the treatment students showed that

two weeks after the unit, they made appropriate connections. Thus, for example, they suggested 'I think because of greenhouse gases such as carbon dioxide trapped the heat from the sunlight' (Adi), 'Carbon dioxide and other greenhouse gases trapped the heat from the sunlight' (Rogayah) and 'Carbon dioxide in the atmosphere trapped the heat from the sunlight' (Amar).

The responses show that even though the students did not yet provide complete illustrations for the causes of global warming, they did in fact talk about the idea of carbon dioxide as one of the greenhouse gases trapped the heat from sunlight and contributes towards global warming. Since the treatment students identified the underlying reason for global warming the question on how to reduce the global warming was posted. The students were asked to respond to the question: 'If we had a way of making sure there was no rubbish in any rivers, is that going to help reduce global warming?' They suggested, for example, 'Hmmm ... rubbish doesn't produce carbon dioxide that can cause global warming. It's just about keeping our environment clean' (Adi), 'I think yes. It can reduce global warming. Because when river is clean, global warming will reduce' (Amar) and 'No. Because global warming happens due to more carbon dioxide trapped the heat from the Sun. It's not related to river pollution' (Rogayah). Mixed responses were obtained for this question. Some students correctly indentified that river pollution is a different environmental issue than global warming. Others incorrectly stated that river pollution might contribute to global warming.

Attitude Towards the Environment

The responses obtained prior to the treatment from comparison and treatment group students generally exhibited little concern for the environment, consistent with lower scores on the *New Environmental Paradigm for Children*. Thus, for example, in the comparison group the responses to the question whether students regularly turned off the air conditioning or other electrical appliances when not in use included 'I don't really care whether it is on or off' (Su), 'No ... it is not my work. Usually my mother or sister will do that' (Amin), 'I don't do it unless my mother asks me to off them. I tend to forget. After using I will just leave the room. I will not really check whether it is on or off' (Adib) and 'No ... because it will be very hot then no use ... because it is hot weather we still need to switch on, better to just leave it on' (Siti). Similar self-ascribed behaviours were evident in the treatment group prior to treatment: 'Sometimes I will turn it off. But most of the time I don't do it unless my mother ask me to switch off' (Adi), 'The fan will be always on in my home. Because it is simply too hot. No one bothers to switch it off. I don't do it' (Ali) and 'No when I get scolding from my parents then I will switch off the light or fan' (Amar). Prior to the study, students in both groups indicated that they would not act according to pro-environmental attitudes unless they were told to so. The students noted that they are not really interested in performing the pro-environmental acts because of inconveniences they would experience, including that of hot weather.

Following the intervention, differences were observed. Thus, the responses to the same question posed to students in the comparison group included 'We have

learned in the class but I don't really care' (Su), 'I will try to turn them off but I tend to forget about it' (Amin), and 'I don't want them off . . . because it will be very hot then' (Siti). Consistent with the quantitative results, students in the treatment group expressed more pro-environmental attitudes. Their responses to the question about turning off electrical appliances and air conditioners included: 'After the activities, it make me realized that I can make a small change at my home such as not use electricity that much and turn off the lights or the television when I'm not using them' (Adi), 'I reduce using electricity. I only use it if really necessary. I don't wait for my parents to remind me' (Adi) and 'I make a point to check before I leave the room making sure all the switches are off' (Ali). Compared to the students from the comparison group, the interview responses reflected somewhat more positive attitudes together with self-reported changes in pro-environmental behaviours.

Treatment Group Students' Views about the 5E Learning Cycle-based Activities

Following the treatment, the interviewer also asked the students from the treatment group about those aspects of the activities that they had found most effective for their learning. The treatment group students suggested that the activities helped them to better understand the issued related on global warming. They found the activities are enjoyable and informative. For example, in response to the question 'Which activity helped you to better understand about global warming?' they suggested

> I liked carbon games activity. I learned how the greenhouse gases like carbon dioxide trapped the heat from the sunlight. I also learned activities that will increase the greenhouse gases in the atmosphere such as burning rubbish or we should use more public transport. (Adi)

or

> I now understand what causes the global warming and what its effect on our climate is . . . I think our first activity that is greenhouse activity that helped me a lot. I could visualize how greenhouse effect happens from power presentation. It was colourful . . . interesting . . . like to learn more about this. (Rogayah)

Discussion and Conclusions

This study was designed to test the effect of a 5E learning cycle-based climate change curriculum on Malaysian primary students' knowledge about the global warming and attitudes towards the environment and the relationship that exist between knowledge and attitude. The results show that treatment group appeared to have helped the students understanding global warming-related issues. This is consistent with various other studies that revealed using the 5E learning cycle approach improved students' achievement, basic science process skills and critical thinking (Budprom et al., 2010), acid–base chemistry (Seyhan & Morgil, 2007), force and motion (Campbell, 2006; Yildiz-Feyzioglu & Ergin, 2012), and states of matter (Bilgin et al., 2013). The

outcomes of the study also confirm studies that reported on the effectiveness of hands-on activities on primary school students' understanding of the issues on global warming (Taber & Taylor, 2009) and increases in knowledge of climate change science when elementary methods course students were taught using inquiry-based science lessons on carbon cycle and the greenhouse effect (Lambert et al., 2012). The improved understanding observed in this study may be due to the dynamic and interactive aspects of the 5E approach. Our classroom observations show that the students were challenged about their understanding of global warming and climate change. Frequently they tended to improve their understanding, as was observed in other studies (Bilgin et al., 2013). The 5E approach provided students with opportunities to construct their own knowledge particularly during the exploration and elaboration phases. In this study, we only investigated achievement differences. Future studies might be designed to include clinical interviews that probe student understanding in depth.

This study shows that students participating in the 5E learning cycle-based climate change curriculum exhibited more positive environmental attitude than those in a course on the same topic taught by means of a teacher-centred, lecture-oriented approach. Despite the climate change curriculum resulted in better understanding the effect size appears to be low. Even though the quantitative results shows smaller effect the qualitative results also exhibited changes in the attitude and the students indicated the changes they have experiences is due to the treatment. If the overall effect is due to the 5E approach, the present study would be consistent with others that demonstrated improved attitudes (Lawson et al., 1989; Siribunnam & Tayraukham, 2009; Soomro et al., 2011). The outcomes of this study confirm those of other studies that investigated the effects of integrating environmental activities. One study reported positive changes in student's attitude towards environment change that followed the integration of green chemistry experiments in the curriculum (Karpudewan et al., 2012; Leeming et al., 1997). In both studies, the treatment group students concurrently improved conceptual understanding of climate change and pro-environmental attitudes. The improved knowledge and attitude observed in this study possibly is due to the nature of 5E learning cycle that requires students to be responsible of their own learning. In other words, the students while going through the five phases of 5E learning cycle are constructing and assessing their own understanding. The active involvement of the students in constructing knowledge enables them to develop positive attitude to the subject. This consequently results in building self-esteem of the students about the subject matter in the case of this study the students' experienced improved self-esteem towards engaging nature-related activities as part of their daily life routine (Karpudewan et al., 2012). Issues concerning climate change, greenhouse gases and global warming are integral component of Malaysian primary science curriculum. In teaching these aspects teachers generally use activities suggested in the curriculum specification as conducted in the comparison group. These activities generally focus to impart knowledge with aim of preparing students for examination. Due to the heavy exam-oriented education system, Malaysian students tend to follow the instruction closely with the purpose of memorising the

subject matter, which might lead to minimal environmental knowledge acquisition (Aini et al., 2011) and attitude (Karpudewan & Chin, 2013). The 5E climate change activities employed in this study would be an alternative for the teachers to adapt and implement in their teaching. Besides delivering positive outcome the activities are feasible to be implemented because the activities address equivalent concepts as the traditional activities.

The results of this study at best demonstrate a weak association between pro-environmental attitude of the students in the treatment group with their knowledge about global warming. This result suggests that knowledge and attitudes are not as strongly related as suggested by other studies (Arcury, 1990; Dhindsa & Chung, 2003; Osborne et al., 2003; Simpson & Oliver, 1990). This is probably because attitude towards environment is a varied construct and may depend on the particularities of the attitudinal object (e.g. panda bears versus snakes or mosquitoes as objects of attitude towards wildlife within natural environments). We, therefore, suggest future studies to specify attitudinal objects related to the environment and, thereby, differentiate the attitude construct. Alternatively, because attitudes and conceptions 'are general possibilities that inherently belong to the collective other' (Roth, 2010, p. 99), shared in/through the medium of talk, future research could take a discourse psychological approach to investigate any relations of knowledge talk and attitude talk. Rather than using different measures for knowledge and attitude subsequently correlated, language (discourse) becomes the single object. Such an approach has shown to be fruitful for understanding (a) students' discourses on the environment, environmental protection and environmental attitudes generally (Zeyer & Roth, 2009) and (b) the meditational effects of discursive repertoires on personal attitude talk (Zeyer & Roth, 2013).

In countries such as Malaysia, where a nation is experiencing exponential progress towards achieving the status of fully developed nation by the year 2020, it is imperative for citizens to be educated about the relationship between environmental behaviour and climate change. At this point, too many citizens still are involved in activities that are damaging to the environment and contribute to the elevation of greenhouse gas levels and global warming. Working with children at the primary level is important because they are less likely to subsequently require 'unlearning' any acquired harmful environmental behaviours (Leeming et al., 1997). Implementing climate change activities as proposed in this study is expected to deliver intended attitude and increased knowledge levels about global warming. This has the potential to lead to more pro-environmental behaviours on a national scale in the future. However, further future research is needed to evaluate how the attitude and knowledge change expected from climate change activities will lead to development of pro-environmental behaviour at a larger, state- or nation-wide scale.

Improved attitudes towards the environment and knowledge about global warming as reported in this study is significantly important in the context of Malaysia to ensure less people are performing environmentally destructive behaviour. However, further research is needed to confirm whether the findings obtained in this study will scale up. Although the quasi-experimental design is by far the most appropriate design to

determine the effectiveness of an instruction strategy in field settings (Frohlich et al., 2013; Gottlieb et al., 2013; Porter et al., 2012), there are certain limitations that emerge from the setting of the research design. One of the main limitations is the teacher effect which was not considered in this study might affect the validity of the data. Thus, for example, the treatment is nested within teachers and schools. Although the quasi-experimental design employed is an acceptable design in measuring the effectiveness of the treatments in everyday settings, where comparison groups without treatment similar to those in psychological laboratories are not feasible (Shadish et al., 2002), this design cannot rule out that the treatment effects are due to particulars of the teacher or whether they are in fact due to the specifics of the 5E curriculum (Creswell, 2012). On the other hand, we used Bonferroni adjusted α-levels to make the study more conservative to counteract over-confidence in any effects. Further studies are warranted to rule out teacher-related effects from curricular effects; moreover, studies are required to tease apart the effects derived from the hands-on part and those derived from the increased levels of social interactions with peers and teacher.

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References

Aini, M. S., Nor Azura, S., & Fakhru'l-Razi, A. (2011). Impact of environmental education on concern, knowledge and sustainable behaviour of primary school. *Health and Environment Journal*, *2*(1), 50–53.

Alp, E., Ertepınar, H., Tekkaya, C., & Yılmaz, A. (2006). A statistical analysis of children's environmental knowledge and attitudes in Turkey. *International Research in Geographical and Environmental Education*, *15*(3), 210–223.

Amburgye, J. W., & Thoman, D. B. (2012). Dimensionality of the new ecological paradigm: Issues of factor structure and measurement. *Environment and Behavior*, *44*(2), 235–256.

Arcury, T. A. (1990). Environmental attitude and environmental knowledge. *Human Organization*, *49*, 300–304.

Atkin, J. M., & Karplus, R. (1962). Discovery or invention? *The Science Teacher*, *29*(5), 45–51.

Barraza, L., & Walford, R. A. (2002). Environmental education: A comparison between English and Mexican school children. *Environmental Education Research*, *8*, 171–186.

Bas, M., Teksoz, G. T., & Ertepinar, H. (2011). Emphasizing local features for effective environmental education: Environmental attitudes of elementary school students living in ancient Halicarnassus (Turkey). *Science Education International*, *22*(2), 119–132.

Bilgin, I., Coskun, H., & Aktas, I. (2013). The effect of 5E learning cycle on mental ability of elementary students. *Journal of Baltic Science Education*, *12*(5), 592–607.

Boyes, E., & Stanisstreet, M. (2012). Environmental education for behaviour change: Which actions should be targeted? *International Journal of Science Education*, *34*(10), 1591–1614.

Budprom, W., Suksringam, P., & Singsriwo, A. (2010). Effect of learning environmental education using 5e-learning cycle with multiple intelligence and teacher's handbook approaches on

learning achievement, basic science process skills and critical thinking of grade 9 students. *Pakistan Journal of Social Science*, *7*(3), 200–204.

Bybee, J. W., & Landes, N. M. (1988). The biological sciences curriculum study (BSCS). *Science and Children*, *25*(8), 36–37.

Bybee, R. W., & Landes, N. M. (1990). Science for life and living. An elementary school science program from the biological sciences curriculum study. *American Biology Teacher*, *52*(2), 92–98.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins, effectiveness, and applications*. Colorado Springs, CO: BSCS.

Campbell, M. A. (2006). *The effects of 5E learning cycle model on students understanding of force and motion concepts*. Retrieved from http://etd.fcla.edu/CF/CFE0001007/Campbell_Meghann_A_200605_ME.pdf

Cardak, O., Dikmenli, M., & Saritas, O. (2008). Effect of 5E instructional model in student success in primary school 6th year circulatory system topic. *Asia-Pacific Forum on Science Learning and Teaching*, *9*(2). Article no. 10.

CBC. (2008, March 29). *Canadians go dark with world for Earth Hour*. Retrieved from CBC News World http://www.cbc.ca/news/world/story/2008/03/29/earth-hour.html

Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation: Design & analysis issues for field settings*. Boston, MA: Houghton Mifflin.

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches*. University of Nebraska, Lincoln: SAGE.

Curriculum Development Centre. (2006). *Curriculum specifications Science Year 5*. Retrieved from http://www.moe.gov.my/bpk/v2/index.php?

Department of Environment and Conservation. (2013). *Education portal*. Retrieved from DEC Education http://education.dec.wa.gov.au/downloads/cat_view/1-airwatch/45-resources.html?limit=25&limitstart=0&order=name&dir=ASC

Dhindsa, H. S., & Chung, G. (2003). Attitudes and achievement of Bruneian science students. *International Journal of Science Education*, *25*, 907–922.

Dunlap, E. R., Van Liere, D. K., Mertig, G. A., & Jones, E. R. (2000). Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues*, *56*(3), 425–442.

Eisenkraft, A. (2003). Expanding the 5E model. *Science Teacher*, *70*(6), 56–59.

Fietkau, H.-J., & Kessel, H. (1981). *Umweltlernen* [Environmental learning]. Koenigstein: Hain.

Frohlich, G., Sellmann, D., & Bogner, F. X. (2013). The influence of situational emotions on the intention for sustainable consumer behaviour in a student-centred intervention. *Environmental Education Research*, *19*(6), 747–764.

Gottlieba, D., Vigoda-Gadota, E., & Haim, A. (2013). Encouraging ecological behaviours among students by using the ecological footprint as an educational tool: A quasi-experimental design in a public high school in the city of Haifa. *Environmental Education Research*, *19*(6), 844–863.

Green Teacher. (2003). *Green Teacher*. Retrieved from http://greenteacher.com/

Hines, J. M., Hungerford, H. R., & Tomera, A. N. (1986). Analysis and synthesis of research on responsible environmental behavior: A meta analysis. *The Journal of Environmental Education*, *18*, 1–8.

Huang, H.-P., & Yore, L. D. (2005). A comparative study of Canadian and Taiwanese grade 5 children's environmental behaviours, attitudes, concerns, emotional dispositions, and knowledge. *International Journal of Science and Mathematics Education*, *1*, 419–448.

Ibrahim, F., & Babayemi, O. (2010). Knowledge and attitude of a group of Nigerian undergraduates towards environmentalism. *Global Journal of Environmental Research*, *4*(1), 47–53.

IPCC. (2007). *Climate change 2007: Synthesis report*. Retrieved from Intergovernmental Panel on Climate http://www.ipcc.ch/index.htm

Karpudewan, M., & Chin, C. K. (2013). Pro-environmental concern among primary school students. *Jurnal Teknologi*, *63*(2), 1–6.

Karpudewan, M., Ismail, Z., & Roth, W. (2012). Promoting pro-environmental attitudes and reported behaviors of Malaysian pre-service teachers using green chemistry experiments. *Environmental Education Research*, *18*(3), 375–389.

Karpudewan, M., Ismail, Z. H., & Mohamed, N. (2009). The integration of green chemistry experiments with sustainable development concepts in pre-service teachers' curriculum: Experiences from Malaysia. *International Journal of Sustainability in Higher Education*, *10*, 118–135.

Karpudewan, M., Roth, W. M., & Chandrakesan, K. (2014). Remediating misconception on climate change among secondary school students in Malaysia. *Environmental Education Research*. doi:10.1080/13504622.2014.891004

Karpudewan, M., Roth, W.-M., & Ismail, Z. (2013). The effect of green chemistry experiments on secondary school students' understanding and motivation. *Asia Pacific Education Researcher*. doi:10.1007/s40299–013–0156-z

Kirk, R. E. (2013). *Experimental design: Procedures for the behavioral sciences* (4th ed.). Thousand Oaks, CA: Sage.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, *8*(3), 239–260.

Kuhlemeier, H., van den Bergh, H., & Lagerweij, N. (1999). Environmental knowledge, attitudes, and behavior in Dutch secondary education. *The Journal of Environmental Education*, *30*(2), 4–14.

Lambert, J. L., Lindgren, J., & Bleicher, R. (2012). Assessing elementary science methods students' understanding about global climate change. *International Journal of Science Education*, *34*(8), 1167–1187.

Lawson, A. E., Abraham, M. R., & Renner, J. W. (1989). *A theory of instruction: Using the learning cycle to teach science concepts and thinking skills [Monograph, Number One]*. Manhattan: National Association for Research in Science Teaching; Kansas State University.

Leeming, F. C., Dwyer, W. O., Porter, B. E., & Cobern, M. K. (1997). Outcome research in environmental education: A critical review. *Journal of Environmental Education*, *24*(4), 239–255.

Llewellyn, D. (2005). *Teaching high school science through inquiry: A case study approach*. Thousand Oaks, CA: Corwin Press.

Makki, M. H., Abd-El-Khalick, F., & Boujaoude, S. (2003). Lebanese secondary school students' environmental knowledge and attitudes. *Environmental Education Research*, *9*(1), 21–33.

Malaysian Meteorological Department. (2009). *Climate change monitoring*. Retrieved from Malaysian Meteorological Department, Ministry of Science, Technology and Innovation http://www.met.gov.my

Manoli, C. C., Johnson, B., & Dunlap, R. E. (2007). Assessing children's environmental worldviews: Modifying and validating the new ecological paradigm scale for use with children. *The Journal of Environmental Education*, *38*(4), 3–13.

Marquart-Pyatt, S. T., Shwom, R. L., Dietz, T., Dunlap, R. E., Kaplowitz, S. A., McCright, A. M., & Zahran, S. (2011). Understanding public opinion on climate change: A call for research. Environment: Science, Policy for Sustainable Development, *53*(4), 38–42.

Marshall, N. M. (1996). Sampling for qualitative research. *Family Practice*, *13*, 522–526.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*, 1049–1079.

Pauw, J. B.-d., & Petegem, P. V. (2011). A cross-cultural study of environmental values and their effect on the environmental behaviour of children. *Environment & Behavior*, *45*(5), 551–583.

Petegem, P. V., & Blieck, A. (2006). The environmental worldview of children: A cross-cultural perspective. *Environmental Education Research*, *12*(5), 625–635.

Porter, D., Weaver, A. J., & Raptis, H. (2012). Assessing students' learning about fundamental concepts of climate change under two different conditions. *Environmental Education Research*, *18*(5), 665–686.

Pruneau, D., Gravel, H., Bourque, W., & Langis, J. (2003). Experimentation with a socio-constructivist process for climate change education. *Environmental Education Research*, *9*(4), 429–446.

Roth, W.-M. (2010). *Language, learning, context: Talking the talk*. London: Routledge.

Rye, J. A., Rubba, P. A., & Wiesenmayer, R. L. (1997). An investigation of middle school students' alternative conceptions of global warming. *International Journal of Science Education*, *19*(5), 527–551.

Seyhan, H., & Morgil, I. (2007). The effect of 5E learning model on teaching of acid-base topic in chemistry education. *Journal of Science Education*, *8*(2), 120–123.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi experimental designs for generalized causal inference*. Boston, MA: Houghton-Mifflin.

Shepardson, D. P., Niyogi, D., Roychoudhury, A., & Hirsch, A. (2012). Conceptualizing climate change in the context of a climate system: Implications for climate and environmental education. *Environmental Education Research*, *18*, 323–352.

Shrigley, R. L. (1990). Attitude and behaviour are correlates. *Journal of Research in Science Teaching*, *27*, 97–113.

Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, *74*, 1–18.

Siribunnam, R., & Tayraukham, S. (2009). Effects of 7-E, KWL and conventional instruction on analytical thinking, learning achievement and attitudes toward chemistry learning. *Journal of Social Science*, *5*(4), 279–282.

Soomro, A. Q., Qaisrani, N. M., & Uqaili, A. M. (2011). Measuring students' attitudes towards learning physics: Experimental research. *Australian Journal of Basic and Applied Sciences*, *5*(11), 2282–2288.

Stamp, N., & O'Brien, T. (2005). GK-12 partnership: A model to advance change in science education. *BioScience*, *55*(1), 70–77.

Stern, P. C. (2000). Toward a coherent theory of environmentally significant behavior. *Journal of Social Issues*, *56*(3), 407–424.

Stern, P. C., Dietz, T., Kalof, L., & Guagnano, G. A. (1995). Values, beliefs and proenvironmental action: Attitude formation toward emergent attitude objects. *Journal of Applied Social Psychology*, *25*, 1611–1636.

Svihla, V., & Linn, M. C. (2012). A design-based approach to fostering understanding of global climate change. *International Journal of Science Education*, *34*(5), 651–676.

Taber, F., & Taylor, N. (2009). Climate of concern—a search for effective strategies for teaching children about global warming. *International Journal of Environmental & Science Education*, *4*, 97–116.

Tan, G.-C. I., Eng Lee, C.-K., & Chuan, G. K. (1998). A survey of environmental knowledge, attitudes and behaviour of students in Singapore. *International Research in Geographical and Environmental Education*, *7*(3), 181–202.

Tikka, P. M., Kuitunen, M. T., & Tynys, S. M. (2000). Effects of educational background on students' attitudes, activity levels, and knowledge concerning the environment. *The Journal of Environmental Education*, *31*, 12–19.

UNEP, U. N. (2012). Retrieved from United Nations Environment Programme: *Environment for development* http://www.unep.org/climatechange/

USEPA, U. S. (2012). *Climate change science*. Retrieved from United States Environmental Protection Agency USEPA http://www.epa.gov/climatechange/science/

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching*, *32*(4), 387–398.

Wu, L. (2012). Exploring the new ecological paradigm scale for gauging children's environmental attitudes in China. *The Journal of Environmental Education*, *43*, 107–120.

Yildiz-Feyzioglu, E., & Ergin, O. (2012). The effects of 5E learning model instruction on seventh grade students' metacognitive process. *Journal of Turkish Science Education*, *9*(3), 55–77.

Zeyer, A., & Roth, W.-M. (2009). A mirror of society: A discourse analytic study of 14–15-year-old Swiss students' talk about environment and environmental protection. *Cultural Studies of Science Education*, *4*, 961–998.

Zeyer, A., & Roth, W.-M. (2013). Post-ecological discourse in the making. *Public Understanding of Science*, *22*, 33–48.

Appendix. Interview Questions

Pre-instruction interview questions

1. What is global warming?
2. What do you understand about global warming?
3. What is the cause for global warming?
4. If we had a way of making sure that there was no rubbish in rivers, is that going to help reduce global warming?
5. Explain how we combat global warming by making sure the rivers are clean?
6. Do you turn off the air conditioning or other electrical appliances when not in use? How often you performed this behaviour?

Post-instruction interview questions

1. What is global warming?
2. What do you understand about global warming?
3. What is the cause for global warming?
4. If we had a way of making sure that there was no rubbish in rivers, is that going to help reduce global warming?
5. Explain how we combat global warming by making sure the rivers are clean?
6. Do you turn off the air conditioning or other electrical appliances when not in use? How often you perform this behaviour?
7. Which activity helped you to better understand about global warming?'