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</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Chew-Hung Chang and Liberty Pascua</td>
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</tbody>
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Uncovering the Nexus Between Scientific Discourse and School Geography in Singapore Students' Understanding of Climate Change

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Abstract
This paper describes a baseline empirical study of Singapore secondary students' understanding of climate change. It reports that despite evidence of significant awareness on the topic, what learners think they know does not match up with what they really know. Like other students around the world, their understanding of the phenomenon is not deep enough for accurate definition, explanation and linking of critical concepts together coherently and correctly. The paper critically examines how the introduction of a new national syllabus in geography in Singapore at grade 9 level considers current developments in scientific discourse and affords the opportunity to help students develop values, knowledge, and skills to engage the climate change topic. The study argues for geographic education to be responsive in addressing gaps identified through updating the curriculum with current scientific discourse and by providing skills for students to engage a growing volume of information on climate change from various media.

Keywords: Climate change, climate change education, school geography, misconceptions

Introduction
Climate change is commonly taught as a derivative of Environmental Education (EE) and Education for Sustainable Development (ESD) (Laessoe et al., 2009 in UNESCO, 2012). With ESD as the framework, Climate Change Education (CCE) is taught in a cross-curricular form, requiring teachers to first understand...
stand the complexity of its science and then integrate these in the teaching and learning of different subject disciplines (UNESCO & UNEP, 2011). Even with a well-defined agenda, however, education as a key avenue and resource for managing climate change remains an untapped opportunity (Anderson, 2012). CCE for mitigation and adaptation stresses the criticality of fostering resilience among individuals and communities (Bonifacio et al., 2010 in UNESCO, 2012). The two-pronged approach is crucial in ensuring that the learners of the 21st century are empowered to make informed decisions and actions in the face of a changing global climate system (Schreiner, Henriksen, Kirkeby, & Hansen, 2005).

Singapore’s education system is designed with Desired Outcomes of Education (DOE) in mind. The goal of education in Singapore is to help students develop “a good sense of self-awareness, a sound moral compass, and the necessary skills and knowledge to take on challenges of the future. They are responsible to their family, community, and country. They appreciate the beauty of the world around them, possess healthy minds and bodies, and have a zest for life” (Ministry of Education, Singapore, 2009). The congruence between the DOE and the aims of CCE is not coincidental in that Singapore’s education system has been known to be responsive to the changing needs of the world (Chang, 2014). Indeed, education for mitigation stresses on sustainability such as showing consumers’ viable practices and lifestyles that would help reduce humankind’s carbon footprint. Translated to the Singapore context, a child is encouraged to be responsible for his/her environment. Further, education for adaptation highlights the importance of practical knowledge and skills needed for persons and societies to adapt to inevitable social, economic, and environmental changes (Anderson, 2012), allowing the child to take on challenges of the future. There remains, however, a paucity of empirical studies on students’ understanding of climate change in Singapore. Consequently, this study will examine the current state of climate change understanding among teenage students in Singapore.

It is a sad fact that CCE is given tangential attention in research and practice as it competes for focus with other equally relevant socio-environmental topics (UNESCO, 2012). The disjoint between the intent of education and its outcome is only evident with the persistence of limited and flawed public understanding on the climate system (Bord, O’Connor, Fisher, 2000; Pruneau et al., 2001). Several studies have shown that students’ knowledge of climate change only mirrors the general public’s widespread confusion about the topic. It is evident that learners’ conceptions are error-prone and lacking in depth as observed across age groups and year level around the world (see Andersson & Wallin, 2000; Cordero, Todd & Abellera, 2008; Daniel, Stanisstreet, & Boyes, 2007; Hansen, 2010; Kilinc, Stanisstreet, & Boyes, 2008; Lee, Lester, Ma, Lambert, & Jean-Baptiste, 2007). Pruneau et al. (2001) saw such trend as a cause of concern, warning that deficient comprehension could encourage the growth of chronic apathy in the long term.
Uncovering the Nexus Between Scientific Discourse and School Geography

Geographic Education and Climate Change

The authors argue that geography offers a viable and useful platform for discussing both the social and the scientific aspects of the phenomenon, although ideally, it should be taught across disciplines. Indeed, with people-environment relationships as one of its central themes, geographic education is at a position to adequately tackle climate science literacy while fully engaging learners in the social aspect of the phenomenon with due emphasis on the impact of anthropogenic actions to the environment (International Geographic Union, 1997).

In Singapore, climate change is learned in geography subjects at the secondary level (grades 7 – 10). While the topic is interspersed in discussions on environmental stewardship in disciplines such as Science, Social Studies, Civics, and Moral Education from primary to secondary school, climate change only becomes overtly defined in the curriculum at secondary 2 (grade 8) geography. The topic is given further emphasis at the upper secondary level (grades 9 and 10). A revamped curriculum in the upper secondary level was introduced in 2014. This new national level curriculum, which includes an entire unit on “Variable Weather and Climate,” is a result of collaboration between the state’s National Climate Change Secretariat (NCCS) and the Ministry of Education (Chang, 2014). The entire topic is organized around three key guiding questions (Singapore Examinations and Assessment Board, 2012):

1. Why do different places experience different weather and climate?
2. What is happening to our Earth’s climate?
3. Is the weather becoming more extreme?

Embedded within these three questions is the requirement for students to engage with the causes, impact, and management of the climate change problem. A range of cognitive engagement from understanding the science to describing the impact and evaluating the management strategies is also required in learning this topic. To some extent, this introduction of the topic at secondary 3 level will reinforce the facts about global warming and climate change that the students have learned at secondary 2, and allow the students to engage in the discourse more effectively. It is for this reason that the current study will focus on Secondary 3 (grade 9 equivalent) students who are around 14 to 15 years of age.

Conceptualizing Climate Change Education

It is important that we clarify what we mean when we say someone has learned something about climate change. From a cognitive engagement perspective, learning outcomes can be described from simple recall of information, to understanding concepts, to solving problems, and to making a decision. While many scholars
have written and debated about taxonomies of learning outcomes (Bloom, 1956; Gagné, 1974; Krathwohl, 2002), there is general agreement in the progression of learning outcomes from simple recall of information to more complex and higher order outcomes, such as understanding concepts and analyzing information. Another dimension of consideration is the domain knowledge about climate change. Chang (in press) proposes examining climate change for its causes, impact, and management dimensions. Indeed, even the Intergovernmental Panel for Climate Change (IPCC) Working Groups one to three were organized around these three themes (IPCC, 2007). Hence, when examining if a student has learned something about climate change, we must be able to describe the nature of cognitive engagement, as well as the domain knowledge that resides in the conceptions of causes, impact, and management discourses of climate change. For example, one would consider being able to evaluate the adaptation strategies to rising sea levels differently from being able to identify the greenhouse gases responsible for global warming. It is through this dual dimensional treatment of the learning outcomes of climate change education that we can begin to discourse about "how much" Singapore students know about the phenomenon. Consequently the key question that this study seeks to address is "How much do secondary 3 students in Singapore know about climate change?" Further, the authors would like to differentiate between what students think they know, what they really know, and what they do not know.

Methods

This study is a first in a series of inquiry on climate change education content, perceptions, and practices in Singapore. The paper describes and explores students' understanding of the topic, and aims to add to the body of literature by providing a contextual understanding of how climate literacy is tackled by the city-state.

This paper reports on the results of a performance task administered to students from eleven secondary schools (high school equivalent) ranging from government, co-ed, private all-girls and all-boys schools. Purposive sampling was employed to ensure a distribution of high- and average-performing schools. A total of 397 students belonging to the Secondary 3 cohort participated in this exercise.

The instrument used was composed of open-form and tick-in-the-box questions meant to draw out students' qualitative understanding of basic climate change concepts. Question 1 asked for the students' explanation of the enhanced greenhouse effect. Question 2 investigated students' awareness of their carbon footprints. Question 3 inspected one's knowledge of the effects of climate change. Questions 2 and 3 were adapted for conceptual fitness from Punter, Ochando-Pardo, and Garcia's (2011) study. The three-question test (Appendix A) was put to-
mies of learning outcomes (Bloom, 1956; s general agreement in the progression of information to more complex and higher concepts and analyzing information. An domain knowledge about climate change. climate change for its causes, impact, and the Intergovernmental Panel for Climate three were organized around these three mining if a student has learned something that resides in the conceptions of causes, climate change. For example, one would upation strategies to rising sea levels diff greenhouse gases responsible for global sional treatment of the learning outcomes an begin to discourse about "how much" nomenon. Consequently the key question much do secondary 3 students in Singa her, the authors would like to differentiate what they really know, and what they do thods nquiry on climate change education con- sapore. The paper describes and explores id aims to add to the body of literature by of how climate literacy is tackled by the f a performance task administered to stu- high school equivalent) ranging from gov- boys schools. Purposive sampling was em- and average-performing schools. A total of y 3 cohort participated in this exercise. d of open-form and tick-in-the-box ques- silitative understanding of basic climate the students' explanation of the enhanced ated students' awareness of their carbon knowledge of the effects of climate change. ceptual fitness from Punter, Ochando-Par e-question test (Appendix A) was put to- gether in a booklet with enough space provided for each item to allow for substan tial elaboration.

Data Analysis

Descriptive statistics such as frequency and percentage reports were generated for each of the items. Additionally, qualitative responses to the performance task answers were coded as four levels of understanding. No understanding was given to statements commonly in the form of generic phrases that did not supply much information about the respondents' knowledge base, or those that did not answer the question directly (e.g., phrases such as global warming, greenhouse gases). Included in this category were answers such as 'I don't know.' Wrong understanding was assigned to answers which had explanations that were mostly erroneous. In contrast, explanations that were mostly accurate but with minor errors detected were coded as limited understanding. Accurate understanding was designated for responses which were accurate and complete. Some students skipped one or two of the items, thus a separate category of No answer was used.

Answers to the open-ended questions were coded for content accuracy by the authors and student research assistants who have read a course on climatology. The coding exercise was structured for three persons, two main coders and one arbitrator, to independently evaluate answers to each of the questions. Prior to the coding process, the team discussed at length the procedure, codes, concepts, and criteria for coding. Model answers were formulated for each item in the questionaire for the coders to base their evaluations on. Inter-rater reliability (IRR) analysis was then employed to confirm consistency of rating and to check for researcher's bias. The arbitrators facilitated discussion and resolution of the issue in events of non-agreement. Cohen's kappa coefficient was calculated to obtain each item's IRR (Table 1).

<table>
<thead>
<tr>
<th>Kappa coefficient</th>
<th>Degree of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 0.750</td>
<td>substantial agreement</td>
</tr>
<tr>
<td>Q2 0.595</td>
<td>moderate agreement</td>
</tr>
<tr>
<td>Q3 0.726</td>
<td>substantial agreement</td>
</tr>
</tbody>
</table>
Findings

In a public survey in 2011, the Singapore NCCS found that 86% of the respondents aged 15 and above felt that it was their responsibility to do something about climate change (NCCS, 2011). Building climate-literate and resilient citizens is a critical yet very challenging task for educators. In Singapore, geography as a discipline is given the primary task of educating the city-state’s young generation of learners. The following discussion describes the results of the research by examining the extent of students’ understanding in the key concepts related to the causes and impact of climate change, including the enhanced greenhouse warming mechanism, individual contribution to greenhouse gases, and the consequent effect of climate change on the physical environment.

The Enhanced Greenhouse Effect

An established consensus in the epistemic scientific community such as the rhetoric advanced by IPCC posits that changes in the global climate system are caused by the enhancement of the greenhouse effect (IPCC, 2007).

Answers to Item 1 elicited mostly irrelevant answers (e.g., an updated house that is green in color) and sketches that neither showed appropriate processes nor made reference to any of the greenhouse gases. Indeed, words and phrases commonly associated with climate change such as global warming, greenhouse gas and air pollution were stated but were not elaborated with explanation. In addition, a good number of participants answered ‘I don’t know’, confirming the respondents’ deficient knowledge about the matter. Hence, the majority of the students (54.4%) have no understanding of the enhanced greenhouse effect. In addition, 8.6% of the respondents skipped the question although they went on to answer all other sections of the test. About 30% of the respondents provided substantial but erroneous responses. Though correct concepts were supplied (e.g., trapping of heat), misconceptions were also prevalent (e.g., inability of sunlight to escape into space, ozone depletion causing the enhancement of the greenhouse effect). Explanations provided were likewise devoid of differentiation between the natural against the enhanced greenhouse effect, with some assuming that both are natural processes. These responses were then deemed as indicative of wrong understanding. Those with limited understanding (6.3%) were able to point to the differences between the natural and the enhanced greenhouse effect but the explanations provided were incomplete. For example, they failed to incorporate and discuss effectively how elements such as infrared radiation, water vapor, and carbon dioxide contribute to the enhancement of the greenhouse effect (Table 2).

Results from this item alone were suggestive of students’ superficial understanding of the phenomenon. The enhancement of the greenhouse effect is the most basic set of concepts students must become familiar with so as to effectively connect the cause to the effects and management strategies for climate change.
CS found that 86% of the responsibility to do something x-literate and resilient citizens.

In Singapore, geography as a city-state's young generation results of the research by the key concepts related to the enhanced greenhouse warm-use gases, and the consequent

In the scientific community such as the global climate system are the (IPCC, 2007). swers (e.g., an updated house ed appropriate processes nor eed, words and phrases com-warming, greenhouse gas and th explanation. In addition, a conf rming the respondents' majority of the students (54.4%) error. In addition, 8.6% of5 went on to answer all other provided substantial but erro applied (e.g., trapping of heat), sunlight to escape into space, enhouse effect). Explanations twin the natural against the at both are natural processes. wrong understanding. Those to the differences between the explanations provided were and discuss effectively how carbon dioxide contribute to the greenhouse effect. Those familiar with so as to effectively strategies for climate change.

Table 2. The enhanced greenhouse effect.

<table>
<thead>
<tr>
<th>Frequency (n)</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No understanding</td>
<td>216</td>
</tr>
<tr>
<td>Wrong understanding</td>
<td>121</td>
</tr>
<tr>
<td>Limited Understanding</td>
<td>25</td>
</tr>
<tr>
<td>Accurate understanding</td>
<td>1</td>
</tr>
<tr>
<td>No answer</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>397</td>
</tr>
</tbody>
</table>

Carbon Footprint

Question 2 in the instrument was designed to detect students' awareness of their contribution to humanity's carbon footprint. First, the students had to select all activities listed that they believe would contribute to climate change. Second, they then had to pick one of the items and explain how the chosen activity could exacerbate climate change.

The majority correctly distinguished using petrol-powered vehicles such as a car (92.4%) or motorcycle (81.4%) as examples of anthropogenic contributors to climate change. Among the common household appliances listed, the air conditioner was most singularly identified to hasten the process (87.4%) while answers were mixed for charging a mobile phone, using a hairdryer, or a heater. Internet usage, listening to mp3 music, playing video games, and hot showers were least considered to be anthropogenic elements to climate change. Almost all of the students identified the three activities pertaining to energy-efficient actions (read in natural light, play football, ride a bicycle) as non-contributors (Table 3).

Table 3. Common activities.

<table>
<thead>
<tr>
<th>Activities</th>
<th>True</th>
<th>False</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge up a mobile phone</td>
<td>212</td>
<td>183</td>
</tr>
<tr>
<td>Use a hairdryer</td>
<td>211</td>
<td>184</td>
</tr>
<tr>
<td>Go to school by car</td>
<td>367</td>
<td>28</td>
</tr>
<tr>
<td>Listen to mp3</td>
<td>99</td>
<td>296</td>
</tr>
<tr>
<td>Turn heater on</td>
<td>223</td>
<td>172</td>
</tr>
<tr>
<td>Download files from the internet</td>
<td>95</td>
<td>300</td>
</tr>
<tr>
<td>Have a hot shower</td>
<td>158</td>
<td>237</td>
</tr>
<tr>
<td>Use air conditioner</td>
<td>347</td>
<td>48</td>
</tr>
<tr>
<td>Ride a motorcycle</td>
<td>323</td>
<td>72</td>
</tr>
<tr>
<td>Play video games</td>
<td>164</td>
<td>231</td>
</tr>
<tr>
<td>Not recycle rubbish</td>
<td>296</td>
<td>99</td>
</tr>
<tr>
<td>Read in natural light</td>
<td>16</td>
<td>379</td>
</tr>
<tr>
<td>Ride a bicycle</td>
<td>22</td>
<td>473</td>
</tr>
<tr>
<td>Play football</td>
<td>15</td>
<td>380</td>
</tr>
</tbody>
</table>
While students think they know what contributes to global warming, the next task of explaining how the items identified contribute to global warming shows how little students understand the mechanism responsible for the phenomenon. This is not incongruent with the findings from the previous item that students are unable to distinguish between the natural and enhanced greenhouse effect. Almost all of the students have chosen to explain ‘Go to school by car’ among the items listed. More than half (52.6%) reasoned erroneously, thus with wrong understanding, that toxic gases such as carbon monoxide acting as a pollutant were the reason for an increase in the carbon footprint. Fossil fuel burning was rarely mentioned as the reason. In addition, air conditioner use was popularly understood as an emitter of chlorofluorocarbons (CFC) and therefore a culprit to climate change owing to its capacity to deplete the ozone layer. Almost one in four of the respondents gave irrelevant answers, which were coded as a no understanding answer. About 16% have limited understanding as they did not fully illustrate how burning of fossil fuels lead to the enhancement of the greenhouse effect.

The results showed that while for the most part students had an ability to identify select human activities that enhances climate change, they did possess a deep understanding of how this occurs, corroborating the findings from the first question (Table 4).

Table 4. Human activities and climate change.

<table>
<thead>
<tr>
<th>Frequency (n)</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No understanding</td>
<td>102</td>
</tr>
<tr>
<td>Wrong understanding</td>
<td>209</td>
</tr>
<tr>
<td>Limited understanding</td>
<td>66</td>
</tr>
<tr>
<td>Accurate understanding</td>
<td>10</td>
</tr>
<tr>
<td>No answer</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>397</strong></td>
</tr>
</tbody>
</table>

Effects of Climate Change

The impact of climate change varies across geographical locations. Some of the forecasted effects are listed below except for the last two entries which were meant to test whether the students were able to differentiate climate related events from other environmental occurrences.

Almost all of the students were convinced that there will be a rise in global temperature (95.5%), many countries’ climate will change (91.9%), there will be more floods (87.4%), and the polar ice caps will melt (98.0%). They were divided over items such as the formation of more deserts and the possibility of crop failures. The consensus leaned more on the perception that these are plausible results.
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next to global warming shows
shows responsible for the phenomenon.
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fuel burning was rarely men-
was popularly understood as
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rate change, they did possess a
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Table 5. Areas needing improvement within geography training.

<table>
<thead>
<tr>
<th>Skills/Topics</th>
<th>All participants</th>
<th>Participants by sector</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number (N=59)</td>
<td>Percent (N=23)</td>
</tr>
<tr>
<td>Employer/industry awareness of the value of a geography degree</td>
<td>18</td>
<td>30.5%</td>
</tr>
<tr>
<td>Providing hands-on/applied experience</td>
<td>13</td>
<td>22.0%</td>
</tr>
<tr>
<td>Career advising/awareness</td>
<td>12</td>
<td>20.3%</td>
</tr>
<tr>
<td>Training in business skills</td>
<td>8</td>
<td>13.6%</td>
</tr>
<tr>
<td>Training in quantitative skills</td>
<td>6</td>
<td>10.2%</td>
</tr>
<tr>
<td>Training in communication skills</td>
<td>6</td>
<td>10.2%</td>
</tr>
<tr>
<td>Developing industry-specific knowledge/skills</td>
<td>5</td>
<td>8.5%</td>
</tr>
<tr>
<td>Programs too narrowly focused on GIS&amp;T</td>
<td>5</td>
<td>8.5%</td>
</tr>
<tr>
<td>Inadequate connections between academic programs and BGN</td>
<td>5</td>
<td>8.5%</td>
</tr>
</tbody>
</table>

Note: Table includes only those skills mentioned by at least five interview participants. Boldface indicates responses given by at least 20% of respondents within a category.

More than half of the respondents (54.9%) were able to discuss the relationship between climate change and the occurrence of a specific climatic event (e.g., rise in global temperature). Reasons provided successfully connected the concepts of temperature increase as a result of the enhanced greenhouse effect, leading to events such as melting of ice caps, increased rainfall, and floods. On the other hand, almost a quarter of the respondents (23.4%) provided answers suggestive of no understanding of the processes involved. Irrelevant answers such as 'Increasing sea levels will flood factories thereby contaminating rivers with the waste from the floods' fall under this category, as well as those that expressed complete lack of knowledge on the matter (e.g., I don't know; I don't understand). Ozone layer depletion and related misconceptions were detected, which were coded as wrong understanding (15.1%). Some have limited understanding (3.8%) with incomplete
answers and insufficient explanations. Such included ambiguous replies such as 'Temperature change hence ice caps melt' without mentioning whether there is temperature increase or decrease involved (Table 6).

Table 6. Understanding of the effects of climate change.

<table>
<thead>
<tr>
<th>Frequency (n)</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No understanding</td>
<td>93</td>
</tr>
<tr>
<td>Wrong understanding</td>
<td>60</td>
</tr>
<tr>
<td>Limited understanding</td>
<td>15</td>
</tr>
<tr>
<td>Accurate understanding</td>
<td>218</td>
</tr>
<tr>
<td>No answer</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>397</td>
</tr>
</tbody>
</table>

While the responses gathered through this question showed a more elaborate understanding of the impact in contrast with the causes of climate change, misconceptions and incomplete comprehension were still prevalent in the afforded explanations.

In considering the items presented above, the students in this study were able to identify human activities that contribute to global warming. While they think they know what contributes to global warming, they were unable to distinguish between the enhanced and greenhouse effect, which shows what they really know if far from sufficient. Indeed, they are unable to explain how the human activity would lead to an increase in greenhouse gas emissions and consequently result in rising average temperatures. While most of the students can explain how climate change will result in warmer temperatures and higher sea levels, a good number of them still held misconceptions about how climate change will result in more earthquakes and volcanic eruptions, for example. This finding is similar to misconception of global warming around the world (Kilinc et al., 2008). For instance, students were usually confused about the facts between environmental problems in a Spanish study (Punter et al., 2011). Given an emphasis on the topic in the revised national curriculum for school geography in 2013, these findings that indicate that students lack deep understanding present a challenge to the successful implementation of the curriculum.

Synthesis and Conclusion

This study adds to the body of literature on climate literacy and thus confirmed that in the Singapore setting students' understanding of climate change is subjected to similar issues as other students around the world. It reports that despite evidence of significant awareness on the topic, learners' content knowledge
Uncovering the Nexus Between Scientific Discourse and School Geography

is restricted to providing one-word answers. Deep understanding of the subject matter is inconsistent and often peppered with unscientific notions.

The prevalence of answers falling under the no understanding and wrong understanding categories raises questions on how much, or how little knowledge the students have learned and retained from their geography lessons in the previous year. Through the aid of descriptive statistics, it provided a picture on the extent of the disjoint in students' conceptual understanding of the phenomenon. For instance, it was widely accepted that vehicles do contribute to the climate change problem, but activities that adolescents are more familiar with and regularly engage in, such as Internet surfing, playing video games, and listening to mp3 music were less known to have detrimental consequences. They were also unable to use the premise of fossil fuel burning in reasoning for anthropogenic climate change. Additionally, there is a pronounced dearth of basic propositional understanding of the processes involved in climate change such as the enhancement of the greenhouse effect. Misconceptions were also detected, many of which have been documented in the literature. These include ozone layer depletion as the cause of global warming (Cordero et al., 2008; Hansen, 2010; Lee et al., 2007) and the tendency to lump all environmental issues and solutions with climate change (Papadimitriou, 2004). These issues raise serious questions for education researchers and policy makers, alike.

In a previous Singapore study conducted in 1998, Grade 9 and 11 students' mean environmental knowledge score was 70.9% (Tan, Lee, & Goh, 1998). The difference, however, between the high scores in the previous study and the lack of understanding presented in this study does not mean that students' environmental knowledge has decreased over time. In the previous study, the instrument used was constructed largely based on brown and green issues of the time, which unsurprisingly did not include any item that tested students' understanding of the enhanced greenhouse warming mechanism. There were a couple of items about carbon dioxide but the responses provided in the multiple choice instrument asked if it will affect the environment and did not ascertain if students could distinguish the role of greenhouse gases in the enhanced warming of the Earth. It is unfair to compare the results of the two studies to begin with, but the comparison raises the question of the prevailing epistemic discourse of its time. The term 'enhanced greenhouse effect' did not come into the school curriculum until its current revision of the school syllabus. Indeed, the scientific community did not begin to elucidate the distinction between natural and greenhouse until the IPCC Third Assessment Report when there was higher confidence that the warming observed is because of human activity. It is perhaps timely that a revision to the national curriculum of school geography in 2013 takes into account an entire learning unit on variable weather and changing climate. It affords the avenue for learners to engage in the updated discourse on climate change, which incorporates the conceptual under-
standing required for students to learn and act on climate change.

In addition, factors outside classroom instruction also influence how students learn about climate change. Mass and online media, for instance, are the top sources of information on the phenomenon (Chang, in press). Indeed, “people in Singapore and the rest of Asia are major users of social media” that engages online content through videos, blog postings and the more traditional news websites (Channel NewsAsia, 2013). The extent to which non-formal learning has an effect to the building of conceptual (mis)understanding is yet to be empirically measured. Nonetheless, the plausibility of such sources to promote awareness through facilitating recall of basic vocabulary on the matter (e.g., greenhouse effect, global warming) while at the same time clouding the learning of proper knowledge cannot be discounted. Indeed, Singapore's DOE suggest that students must also be equipped with skills to engage the challenges of the future. In this regard, the ability to critically engage the information one receives, compare it with what one knows and by triangulating it to multiple reliable sources of information is an essential skill that students will need in managing the huge volume of information that he/she receives from various media sources.

This study reiterates that the mere factual recall of knowledge about the issue is insufficient for advancing a climate change curriculum in schools. Indeed, being able to recall terms such as global warming or greenhouse gases should not be considered as sufficient evidence of learning. This study has shown that mere recall does not equate to content knowledge that is deep enough to allow the learners to effectively define, explain and link concepts together. What is needed is an explicit articulation of the enhanced greenhouse warming mechanism, for example. The discussion on the effects and management strategies of climate change should be linked back to the elements that cause the enhancement of the greenhouse effect, thus filling the gaps in their conceptual understanding.

Geographic education in Singapore has developed to a point where a new revised national curriculum affords the opportunity to remedy the problems that has plagued climate change learning. It is in an ideal platform to discourse the critical issues of climate science and the socio-environmental aspect of climate change. It is evident in this research that geographic learning needs an epistemic update to address students' knowledge gap. In particular, the deliberate distinction between the natural and enhanced greenhouse effect will help students learn about the mechanism responsible for anthropogenic climate change. Whether this new curriculum will improve the overall state of climate change understanding is yet to be seen. Nonetheless, it is crucial that climate change educators take the initiative to upgrade their content knowledge and pedagogical content knowledge in teaching the topic. One of the key strategies that can be undertaken will be through teacher professional learning activities which will provide a platform for teachers to examine their current understanding on the subject matter and the pedagogies
climate change, action also influence how stu-media, for instance, are the top g, in press). Indeed, "people in social media" that engages on more traditional news websites n-formal learning has an effect is yet to be empirically mea-to promote awareness through (e.g., greenhouse effect, glob-learning of proper knowledge suggest that students must also the future. In this regard, the ives, compare it with what one sources of information is an es-e huge volume of information l of knowledge about the issueulum in schools. Indeed, being enhouse gases should not be study has shown that mere re-p enough to allow the learners ther. What is needed is an ex-ning mechanism, for example. gies of climate change should cement of the greenhouse ef-tanding. oped to a point where a new y to remedy the problems that lead platform to discourse the vironmental aspect of climate ic learning needs an epistemic ular, the deliberate distinction t will help students learn about ate change. Whether this new change understanding is yet to ge educators take the initiative ll content knowledge in teach- e undertaken will be through rovide a platform for teachers ect matter and the pedagogies for teaching the topic on climate change.

As nations struggle to develop and agree on international accords that would curb further greenhouse gas emissions, the responsibility that faces any human being is one of personal action, driven by a moral responsibility and the skills and knowledge to take on this environmental challenge. A critical review of how school geography curriculum can reflect the current scientific discourse and equip students with the skills to process and consume the burgeoning volume of information from the media will be instrumental to ensure that geography will help students develop values, skills, and knowledge to this end.

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