

# An Investigation on High School Students' Understanding and Misconceptions of the Greenhouse Effect In Brunei Darussalam

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**ABSTRACT:** *The greenhouse effect is one of the environmental issues which has been widely discussed in media and science education and in science curriculum. This study aimed to assess Bruneian high school students' understanding of the GHE before formal teaching was conducted. This study involved 209 Year 9 and Year 10 students from a private school in Brunei Darussalam. The GHE Questionnaire, which consisted of two open-ended questions and five closed-ended questions, was used to probe the students' understanding of the important concepts of the GHE from seven aspects. The sources of the students' knowledge concerning this issue were identified using a 3-scales Likert scale. Descriptive statistics were used to present the students' responses to the instrument. This study found that the students held both informed and naïve conceptions of the GHE. Their knowledge about the definition and mechanism of the GHE was insufficient. The majority of the students demonstrated a conflation of ideas between the GHE and other environmental issues. This study suggests that teachers should focus on identification of students' understanding of the GHE and build on these ideas as the basis for lesson planning.*

**KEYWORDS-** *high school students, GHE, understanding, misconceptions*

## I. INTRODUCTION

Schools need to respond to social changes, as well as various societal issues including environmental issues. While the debates on environmental issues such as global warming, the greenhouse effect (GHE) and ozone depletion are complex, participations from school students are vital. Since students are decision makers and policy implementers of tomorrow [1][2], their informed understanding of environmental issues is indispensable. This can ensure that they can make wise decisions for the betterment of mankind and society [3].

The GHE is one of the environmental issues which has been widely discussed in media and science education and in science curriculum [4]. A number of studies have been conducted to investigate primary school students [5][6][7] and secondary school students' [4][8][9] understanding of this issue. The findings of these studies showed that misunderstandings of GHE were prevalent among students, regardless of their educational level. However, teachers often minimize the time, or even ignore the environmental topics in the science curriculums, especially when they are running out of time to cover the syllabus. Thus, students' preconceptions and misconceptions of these environmental issues are not thoroughly probed [1]. Developing students' knowledge on environmental issues should start with assessing their alternative conceptions of these issues in order to plan practical environmental education.

Research on Bruneian high school students' environmental knowledge, including GHE (GHE) is scarce. Content knowledge about the GHE which includes its mechanism, factors, consequences and mitigation methods are not explicitly discussed in science curricula and science textbooks. This study aimed to assess Year 9 and Year 10 students' understanding of the GHE in terms of: (a) definition of the GHE; (b) natural and

anthropogenic of the GHE; (c) types of the greenhouse gases; (d) mechanism of the GHE; (e) factors contributing to the GHE; (f) consequences of the GHE; and (g) ways to mitigate the GHE.

## II. LITERATURE REVIEW

### 2.1 Students' understanding of GHE

As an accompaniment to the concerns with the environment, a number of studies have been conducted to investigate primary school students [1][5][6][7], secondary school students [8][9][10][11][12] and teachers' conceptions [8][17] on the GHE. Generally, previous research reported that students had vague and superficial knowledge on the GHE, including the role of GHE to global warming as well as the causes, effects and ways to reduce the GHE[8][9]. Research had indicated that both teachers and students were confused over the relationship between GHE, ozone layer depletion and other environmental issues [1][2][6][8][9][13]. For example, Koulaidis and Christidou [6] found that primary school students viewed the GHE and the ozone layer depletion as "one". They had erroneously thought that the ozone layer absorbs the heat of the sun radiation, resulting in GHE. Secondary school students in research by Boyes and Stanisstreet [9] held the same misconception, believing that chlorofluorocarbons (CFCs) exacerbate the GHE[9]. In addition, students also held the misconceptions that increased ultraviolet radiation due to the ozone layer depletion causes GHE as ultraviolet (UV) radiation can transfer heat [6][12].

The research by Boon [8] and Francis et al. [1] shared similar results as the previous studies. Boon [8] found that the secondary students in her research invoked trapped heat or "light" by the ultraviolet radiation as a factor of the GHE. Research carried by Francis et al. [1] on primary students explained that they tended to make a generalization for all the environmental problems. They assume that all the factors contributing to air pollution and ozone layer depletion such as emission of gasoline and aerosol gases will result in the GHE.

Fisher [5] found that the conception that ozone hole allows more radiation to penetrate the Earth was prevalent among students. In an earlier study by Boyes and Stanisstreet [9], the secondary students thought that GHE is the result of "hole" in the ozone layer. This allows "too much" sun rays to enter the Earth. Research by Koulaidis and Christidou [6] supported the above findings. They added that students believed that ozone hole causes an increase in the amount of UV radiation, which in turn warms the Earth and causes climate change.

In terms of greenhouse gases, previous studies found out that the students demonstrated a lack of knowledge on the different types of greenhouse gases [2][5][8]. Shepardson et al. [2] found that only a minority of the students held scientific knowledge understanding of greenhouse gases. They could not identify other types of greenhouse gases except carbon dioxide [2]. Research by Boon [8] further indicated that Australian secondary school students and the pre-service teachers in his study could not name greenhouse gases such as CFCs, nitrous oxides, methane or water vapour.

### 2.2 High School Environmental Education in Brunei

Environmental education is not taught as a separate subject in Bruneian high school (Year 9 to Year 11). Environmental issues such as air pollution, water pollution, deforestation and global warming are integrated into science subjects. For pure science classes, environmental issues, including the effects of humans on environment, pollution and conservation are discussed under the topic "Relationships of organisms with one another and with the environment" [14] in biology syllabus. Greenhouse gases such as carbon dioxide and methane are depicted as factors contributing to air pollution and global warming [14]. Besides, students are exposed to common atmospheric pollutions such as carbon monoxide, methane and sulphur dioxide during chemistry classes. The sources of pollutants, effects of pollutants on environment and human health, chemical reactions which can solve pollution issues and importance of ozone layer are also discussed. Students are required to describe global warming and its relationship with greenhouse gases [15].

Similarly, students from art classes learn about environmental issues under the topic “Relationships of Organisms with One Another and with the Environment” and “Atmosphere and Environment” in Combined Science [16]. In the biology section, students are required to describe the effects of humans on rainforest, oceans and rivers. Global issues such as famine and air pollution are also discussed [16]. The names, sources and effects of pollutants (e.g., carbon monoxide, sulphur dioxide, oxides of nitrogen and lead compounds) are also discussed under the chemistry section.

### III. METHODOLOGY

The first paragraph under each heading or subheading should be flush left, and subsequent paragraphs should have a five-space indentation. A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

#### 3.1 Participants

This study involved 209 Year 9 and Year 10 students from a private school in Brunei. They consisted of 121 females and 88 males. The students aged between 14 to 16 years old as they admitted into school at different age. 115 students were Y9 students while the remaining were Y10 students. 97 of the respondents were science-stream students while 112 were students from art classes. The participant profiles are shown in Table 1.

Table 1. Background information of participants

Demographic Background	Total Frequency (Percentages)
Gender	
Male	88 (42.1%)
Female	121 (57.9%)
Age (years old)	
14	64 (30.6%)
15	83 (39.7%)
16	62 (29.7%)
Class	
Year 9	115 (55.0%)
Year 10	94 (45.0%)
Stream	
Science	97 (46.4%)
Art	112 (53.6%)

#### 3.2 Data Collection

The data was collected in the form of a questionnaire. The students were given an hour to answer the questionnaire. The researcher conducted the research in all classes to make sure that the same procedures were applied during the study.

#### Instrument - GHE Questionnaire (GHEQ)

The GHE Questionnaire (GHEQ) was used to assess the students' understanding of the GHE before they learned about GHE during formal learning in school. The GHEQ was partially adapted and modified from the a few previous research [2][9][17][18] to ensure it covered all the important aspects of the GHE. The GHEQ consisted of two open-ended questions and five closed-ended questions related to the GHE as summarised in Table 2.

Table 2. Summary of GHE Questionnaire

Question	Topics	Descriptions
Question 1	Definition of GHE	Open-ended questions
Question 2	Natural and anthropogenic of GHE	
Question 3	Types of greenhouse gases	Closed-ended questions with 12
Question 4	Mechanism of GHE	statements. Students chose
Question 5	Factors contributing to GHE	between three options: "Right",
Question 6	Consequences of GHE	"False" and "Not sure"
Question 7	Cures of GHE	

The students' understanding of the definition of the GHE was assessed in Question 1. Question 2 aimed to probe the students' understanding of the natural and the anthropogenic GHE. All the respondents had to write their answers in the blanks provided. The remaining closed-ended questions (Question 3 to Question 7) were similar to that used by Boyes and Stanisstree [9] to assess the British students' ideas on the factors that exacerbate the GHE, the consequences of the GHE and the ways to reduce the GHE. A few items were added into the original questionnaire to probe the students' concerns about different types of greenhouse gases and the mechanism of the GHE. These statements were adapted from the questionnaire used by Gautier et al. [17] to assess the students' misconceptions on the GHE. Each closed-ended item in the GHEQ consisted of 12 statements except Question 4 and Question 5. The correct statements which were consistent with the scientific views were distributed randomly among the other six "scientifically unaccepted" statements. The "scientifically unaccepted" statements were some alternative conceptions held by most of the British secondary students involved in the previous research [9]. To answer these items, students were asked to respond by ticking one of the three columns labeled "Right", "False" and "Not sure". The column "Not sure" was prepared to avoid students from simply guessing and providing an answer for the statements.

### 3.3 Data Analysis

The students' responses to the GHEQ were collected and analysed. The students' answers for Question 1 and Question 2 were coded. All data was coded by two coders until consensus was reached. The first author was one of the coders. The second coder is an academic at a US-based university with no direct involvement with this study other than being a coder and peer debriefer. Students' responses which represented the same ideas were classified and grouped into the same themes. An example of the students' answer for Question 1 is shown below:

GHE is a phenomenon in which the heat from the sun radiation being trap in the Earth by certain greenhouse gases such as chlorofluorocarbon (CFC), carbon dioxide and nitrogen dioxide. The heat being trap inside the atmosphere cause the temperature of Earth to increase or global warming, melting of iceberg, increase the level of sea water and subsequently cause the flood to occur at low-lying area and drought.

An example of analysing and categorizing the students' responses for Question 1 is shown in Table 3.

Table 3. An example of analysing students' responses for Question 1

Categories	Students' responses
Causes of the GHE	<sup>1</sup> (The heat from the sun radiation being trap in the Earth by certain greenhouse gases) such as chlorofluorocarbon (CFC), carbon dioxide and nitrogen dioxide.
Consequences of the GHE	<sup>1</sup> (The heat being trap inside the atmosphere cause the temperature of Earth to increase or global warming), (melting of iceberg), <sup>2</sup> (increase the level of sea water) and subsequently cause the

<sup>3</sup>(flood to occur at low-lying area) and <sup>4</sup>(drought).

Notes: Superscript is used to represent a new idea.

The answers for the closed-ended questions were presented in the form of a table of description. For the rest of the questions, descriptive statistics were presented. Frequencies (f) and percentage values (%) for the three options “Right”, “False” and “Not Sure” were computed using SPSS.

#### IV. RESEARCH FINDINGS

The following section presents the Year 9 and Year 10 students’ understanding of GHE.

##### 4.1 Definition of the GHE

The students gave a wide range of definitions for the GHE. As shown in Table 4, they defined the GHE from four different aspects: (1) relationship between the GHE and other phenomena; (2) GHE and solar radiations; (3) causes of the GHE; (4) consequences of the GHE and (5) a combination of different categories.

Only 4% (f=7) of the students could explain the mechanism of the GHE. They related the GHE with the long and short wavelength. Some of them used the general term “sunlight” to indicate the wavelength that enters the Earth. Approximately 10% (f=21) students explained that GHE equated to other natural phenomenon such as ozone layer depletion, air pollution and global warming. About 20% (f=43) students defined the GHE from the aspect of its causes. Most of the students provided scientifically accepted answers such as “GHE is caused of the trapping of heat by greenhouse gases” and “deforestation causes GHE as carbon dioxide traps heat.” The students also held some misconceptions about the causes of the GHEs, responding that “GHE is caused by the holes in the ozone layer, which allows more sunlight to enter the Earth” and “Haze causes GHE.”.

The students (f=49, 23.4%) who defined the GHE from the perspective of its consequences held both informed and uninformed knowledge on this issue. Some of the informed responses included “GHE causes climate change, melting of icebergs at the two Poles and floods”. They also explained that “GHE damages the habitat of living things”. The students’ responses also revealed that they had misconceptions about the consequences of GHE. For example, they explained that this phenomenon causes earthquakes and air pollution. They also mistakenly thought that GHE causes skin cancer and influenza.

Table 4. Students’ understanding of definition of GHE

Categories	Examples		
	f	%	
Natural phenomena	21	10.0	<ul style="list-style-type: none"> <li>• GHE is pollution</li> <li>• GHE is global warming</li> <li>• GHE is thinning of ozone layer</li> </ul>
Mechanism of the GHE	7	3.5	<ul style="list-style-type: none"> <li>• Sunlight entering the Earth is reflected into the space</li> <li>• Greenhouse gases absorb short-wave length radiation and reflect long-wave length</li> <li>• Heat in the form of infrared is radiated into the space</li> </ul>
Causes of GHE	43	20.6	<ul style="list-style-type: none"> <li>• Trapping of heat by greenhouse gases</li> <li>• Deforestation</li> <li>• Ozone layer depletion</li> <li>• Air pollution (e.g., open burning, unleaded petrol)</li> </ul>
Consequences	49	23.4	<ul style="list-style-type: none"> <li>• Climate changes (temperature rises or drops)</li> </ul>

			<ul style="list-style-type: none"> <li>• Ozone layer depletion/ more sunlight enters the Earth</li> <li>• Natural disasters (e.g., flood, earthquake, melting of icebergs)</li> <li>• Harmful effects to living things (humans, animals and plants)</li> </ul>
Combination of at least two categories	89	42.6	<ul style="list-style-type: none"> <li>• GHE is caused by cutting of trees and smoke from factories. It increases the temperature of the Earth and causes icebergs to melt. Flash flood will occur.</li> <li>• GHE is thinning of ozone layer. It allows more sunlight to enter the Earth. More heat is trapped, and the Earth becomes warmer.</li> </ul>

More than 40% of the students (f=89) provided more elaborated responses about the GHE, linking the causes and effects of the GHE. For instance, they explained that “GHE is caused by trapping of heat by greenhouse gases. This causes an increase in the temperature. Iceberg at Artic melts, causing polar bears to lose habitat and floods to some countries.”. However, they also erroneously related this phenomenon to ozone depletion, explaining that GHE allows sunlight to penetrate the Earth, causing skin cancer.

#### 4.2 Natural and Anthropogenic GHE

Table 5 shows that the students were less informed about the natural and anthropogenic GHE. Not all of them understood that GHE impacted life on the Earth and natural surroundings. Approximately 60% (f=122) of the students only acknowledged the negative impacts of the GHE on living things (i.e., human beings, animals and plants) and environment. The students could give scientifically accepted responses such as “GHE might cause wilting and heat stroke due to high temperature”. However, they contributed to all types of diseases, including skin cancer and asthma to the GHE. They also thought that production of harmful gases and thinning of ozone layer could be attributed to the GHE.

Only 14 students (6.7%) thought that the GHE merely brought positive impact to living things and natural environment. They held misconceptions that GHE “produces” oxygen and carbon dioxide to support life. They also explained that GHE reduces its carbon footprint as it absorbs carbon dioxide. The remaining students (f=73, 34.9%) were aware that GHE had both positive and negative impacts on living things and environment. Their answers could be categorised as (a) Good for environment, bad for living things; (b) Good for living things, bad for environment; (c) Good or bad for environment; and (d) Good or bad for living things.

Table 5. Students’ understanding of natural and anthropogenic GHE

Options	Frequency		Reasons
	f	%	
Good	14	6.7	<ul style="list-style-type: none"> <li>• Positive effects to living things (e.g., produces oxygen for animals, produces carbon dioxide for plants)</li> <li>• Good for environment (e.g., minimise carbon footprint)</li> </ul>
Bad	122	58.4	<ul style="list-style-type: none"> <li>• Harmful to living things:                             <ol style="list-style-type: none"> <li>a. Humans (e.g., eye, nose and throat irritation, asthma, cancer, mutation)</li> <li>b. Animals (e.g., death, extinction)</li> <li>c. Plants (e.g., wilting, extinction)</li> </ol> </li> <li>• Environment (e.g., global warming, production of harmful gases, ozone layer depletion)</li> </ul>
Good and Bad	73	34.9	<ul style="list-style-type: none"> <li>• Good for living things, bad for environment</li> </ul> Examples: <ol style="list-style-type: none"> <li>a. It causes the world to increase in temperature, causing flood. Melting ice provides more breeding ground for</li> </ol>

			marine animals.
			b. It is useful in photosynthesis, but it causes global warming.
			• Good for environment, bad for living things
			Example:
			a. It keeps the Earth warm. It causes the ozone layer to deplete, and humans will get skin cancer.
			• Can be good or bad for environment
			Examples:
			a. Without it the Earth will be too cold. Too much greenhouse gases makes the earth hotter.
			• Can be good or bad for living things
			Examples:
			a. It helps in photosynthesis. Greenhouse gases traps heat and causes heat stroke.
			b. It damages cells in living things, but it helps to kill harmful microorganisms.
No effect	0	0	Unavailable

### 4.3 Greenhouse Gases

The distribution of the students' ideas of the types of greenhouse gases is shown in Table 6.

Table 6. Students' understanding of types of greenhouse gases

Codes	Gases	Students' Responses					
		True		False		Not Sure	
		f	%	f	%	f	%
301	Oxygen	50	23.9	127	60.8	32	15.3
302	*Carbon dioxide	172	82.3	18	8.6	19	9.1
303	Hydrogen	40	19.1	95	45.5	74	35.4
304	Carbon monoxide	149	71.3	27	12.9	33	15.8
305	*Chlorofluorocarbons (CFCs)	127	60.8	15	7.2	67	32.1
306	*Methane	60	28.7	41	19.6	108	51.7
307	*Nitrous oxide	71	34.0	28	13.4	110	52.6
308	Sulphur dioxide	101	48.3	32	15.3	76	36.4
309	*Ozone	56	26.8	82	39.2	71	34.0
310	*Water vapour	49	23.4	124	59.3	36	17.2
311	Chlorine	31	14.8	73	34.9	105	50.2
312	Ammonia	31	14.8	66	31.6	112	53.6

Notes: \* = scientifically accepted answers

The results showed that the students only held informed ideas on one-fourth of the statements (statement 301, 302, 303 and 305). Nearly 60% of the students (f=50) were aware that oxygen (statement 301) would not cause the GHE. The most well-known greenhouse gas for the students was carbon dioxide (f=172, 82.3%, statement 302). About 50% of the students (f=40) in the current study could point out that hydrogen (statement 303) was not greenhouse gases. About six-tenths of them (f=127) named CFCs (statement 305) as one of the greenhouse gases.

About 30% of the students (f=31) knew that chlorine (statement 311) and ammonia (statement 312) did not contribute to the GHE. Approximately one-tenth of the students (f=149) knew that carbon monoxide

(statement 304) was not a dominant greenhouse gas. More than 50% of the students were not sure whether methane (f=108, statement 306), nitrous oxide (f=110, statement 307) and ammonia (f=112, statement 312) was as one of the greenhouse gases. Only 26.8% of the students (f=56) could identify ozone (statement 309) as one of the greenhouse gases. Nearly 50% of the students thought that sulphur dioxide (f=101, statement 308) was also a GHE. Most students linked sulphur dioxide to air pollution, which in their minds, is a cause of the GHE. Few students (f= 49, 23.4%) appreciated the role of the water vapour (statement 310) in causing the GHE. The findings of this study showed that water vapour was also the least known greenhouse gases among the students.

#### 4.4 Mechanism of the GHE

Students' answers for Question 4 are shown in Table 7. Overall students could not identify the true answers for all statements. The number of students who were uncertain about the answers of the statements exceeded 50% for four (statement 403, 404, 405 and 406) out of six statements in the questionnaire. Less than one-third of the students (f=56, 26.8%) knew that the transparency of the atmosphere allows shortwave radiation to enter the Earth (statement 401). A low percentage of students (f=73, 34.9%) believed that shortwave radiation would be absorbed or reflected by the surface of the Earth (statement 402). The students who were unsure (f=118, 56.5%) about the types of radiation emitted by the Earth (statement 403) were far more than the students choosing the correct answers (f=37, 17.7%).

Table 7. Students' understanding of mechanism of GHE

Codes	Statements	Students' Responses					
		True		False		Not Sure	
		f	%	f	%	f	%
401	*The Earth atmosphere only allows shortwave radiation from the sun to go through.	56	26.8	78	37.3	75	35.9
402	*Shortwave radiation is either absorbed or reflected by the surface of the Earth (also reflected by some clouds).	73	34.9	37	17.7	99	47.4
403	*The Earth radiates infrared once it is heated by the sun's rays.	37	17.7	54	25.8	118	56.5
404	All the greenhouse gases absorb electromagnetic radiation of the same wavelengths.	76	36.4	27	12.9	106	50.7
405	Shortwave radiation is the main wavelength causing the GHE.	44	21.1	42	20.1	123	58.9
406	*Infrared is an example of long-wave radiation absorbed by the greenhouse gases.	53	25.4	44	21.1	112	53.6

Notes: \* = scientifically accepted answers

It was also found that about only 13% of the students (f=27) knew that different greenhouse gases absorb electromagnetic radiations at different wavelengths (statement 404). An equal number of students (f=44, 21.1%) thought that shortwave radiation caused GHE (statement 405) and named infrared as one of the long-wave radiations contributing to the GHE (statement 406).



#### 4.5 Causes of GHE

Table 8 shows the factors contributing to the GHE. Approximately 80% of the students were well-informed that the presence of excessive carbon dioxide (f=167, statement 503), burning of fossil fuels (84.2%, statement 513) and deforestation (78.5%, statement 514) would result in the GHE. A high number of students (f=150, 71.8.3%) knew that CFCs (statement 509) contributed to the GHE. About 60% of the students (f=125) understood that the gas from the artificial fertilizers (Statement 510) would cause the GHE. More than 70% of the students also held the informed views that rubbish on the road would not cause GHE (f=86, statement 505) while heat entrapment (f=126, statement 512) and deforestation (f=164, statement 514) could exacerbate the GHE.

Table 8. Students' understanding of causes of GHE

Codes	Statements	Students' Responses					
		True		False		Not Sure	
		f	%	f	%	f	%
501	Rubbish is dumped into the rivers and streams	90	43.1	79	37.8	40	19.1
502	Too many sun's rays get to the Earth	112	53.6	55	26.3	42	20.1
503	*Too much carbon dioxide in the air	167	79.9	15	7.2	27	12.9
504	*Too much ozone near the ground	64	30.6	61	39.2	84	40.2
505	Too much rubbish on the roads	71	34.0	86	41.4	52	24.9
506	*Gas from rotting waste	149	71.3	18	8.6	42	20.1
507	Radioactive waste from nuclear power stations	137	65.6	28	13.4	44	20.6
508	Acid in the rain	116	55.5	46	22.0	47	22.5
509	*Chlorofluorocarbons (CFCs) from spray cans	150	71.8	15	7.2	44	21.1
510	*Gas from artificial fertilizers	125	59.8	27	12.9	57	37.3
511	Holes in the ozone layer	121	57.9	29	13.9	59	28.2
512	*Sun's rays cannot escape from the Earth	126	60.3	38	18.2	45	21.5
513	*Burning of fossil fuel	176	84.2	10	4.8	23	11.0
514	*Deforestation	164	78.5	23	11.0	22	10.5

Notes: \* = scientifically accepted answers

About three-tenths of the students (f=64, 30.6%) appreciated the ground-level ozone (statement 504) as a contributor to the GHE. Slightly more than seven-tenths of the students (f=149, 71.8%) thought that gas from the rotting wastes (statement 506) and radioactive wastes (statement 507) were responsible for causing the GHE. Some common misunderstandings held by more than two-thirds of the students were that rubbish-dumping (f=90, 43.1%, statement 501), too many sun's rays (f= 112, 53.6%, statement 502), radioactive wastes (f=137, 65.6%, statement 507), acid rain (f=116, 55.5%, statement 508) and holes in the ozone layer (f=121, 57.9%, statement 511) were detrimental to the GHE.

#### 4.6 Consequences of the GHE

The distribution of students' understanding concerning the consequences of the GHE is shown in Table 9. Most of the students could answer this question well with only four uninformed views identified (statement 603, 604, 605 and 607). Approximately 90% of the students knew that the GHE would cause an increase in the temperature of the world (f=1822, statement 601). About eight-tenths of the students reaffirmed the views that the GHE would result in the climate change (f=168, statement 608) and ice-melting at the Poles (f=160, statement 611).

Less than 15% of the students thought that an increase in the temperature would lead to food poisoning (f=31, statement 602) and earthquakes (f=35, statement 612). Only half of the students (f=107, 51.2%) attributed the poisons in the water (f=98, statement 604) and existence of more deserts (f=107, statement 610) to the GHE. More than half of the students (f=13, 58.9%) held the naïve concept that GHE would cause skin cancer (Statement 605). Nearly two-fifths of the students (f=83, 39.7%) believed that the GHE would contaminate the water supplies, causing the water unsafe to be drunk (statement 606).

Table 9. Students' understanding of consequences of GHE

Codes	Statements	Students' Responses					
		True		False		Not Sure	
		f	%	f	%	f	%
601	*The earth will get hotter	182	87.1	8	3.8	19	9.1
602	More people will get food poisoning	31	14.8	123	58.9	55	26.3
603	*There will be more flooding	83	39.7	84	40.2	42	20.1
604	More fish will be poisoned in the rivers	98	46.9	62	29.7	49	23.4
605	More people will get skin cancer	123	58.9	33	15.8	53	25.4
606	Our tap water will become unsafe to drink	83	39.7	63	30.1	63	30.1
607	*There will be more 'bugs' and 'pests' on crops	62	29.7	72	34.4	75	35.9
608	*There will be drastic change in the world's weather	168	80.4	13	6.2	28	13.4
609	More people will die of heart attacks	42	20.1	88	42.1	79	37.8
610	*There will be more deserts in the world	107	51.2	41	19.6	61	29.2
611	*More ice at the North and South Poles will melt	160	76.6	19	9.1	30	14.4
612	There will be more earthquakes	35	16.7	95	45.5	79	37.8

Notes: \* = scientifically accepted answers

Surprisingly, rather a low percentage of students (f=83, 39.7%) realized that the GHE would result in more flooding (statement 603). Nonetheless, the students failed to develop a more complex chain of reasoning to relate the flooding with ice-melting. Even fewer students (f=62, 29.7%) apprehended that the increased number of pests (statement 607) was due to the intensified GHE.

#### 4.7 Ways to Reduce the GHE

The data of the students' responses concerning the ways to reduce the GHE is shown in Table 10. There was little uncertainty in the contribution of tree planting (f=25, 12.0%, statement 706), reduction of car use (f=32, 15.3%, statement 712) and use of recycled paper (f=16, 7.7%, statement 708) in reducing the GHE. About a fourth tenth of the students understood that consuming healthy food (f=114, 54.5%, statement 702) and reducing starvation (f=81, 38.9%, statement 711) would not help in curing the GHE respectively. About 65% of the students agreed that reducing car use (f=134, statement 712) could mitigate the GHE.

Only 34.4% of the students were certain about the contribution of the nuclear power stations (f=72, statement 701) in ameliorating the GHE. On the other hands, about half of the students believed that keeping the cleanliness of beaches (f=104, statement 703), protecting rare flora and fauna (f=90, statement 709) and saving electricity (f=115, statement 710) would help in the reduction of the GHE. About seven-tenths of the students

(f=141, 67.5%) appreciated the role of alternative energy (statement 707) in reducing GHE. Two misunderstandings which were prevalent among the students in the previous studies were also detected in the present study. First, about half of the students believed that using unleaded petrol (f=103, statement 704) could mitigate the GHE. Second, more than 60% of the students thought that a reduction in the number of nuclear bombs (f=132, statement 705) could mitigate the GHE.

Table 10. Students' responses concerning the ways to reduce the GHE

Codes	Statements	Student's Responses					
		True		False		Not Sure	
		f	%	f	%	f	%
701	*Having nuclear power stations instead of coal power stations	72	34.4	88	42.1	49	23.4
702	Eating healthy food	51	24.4	114	54.5	44	21.1
703	Keeping beaches clean	104	49.8	60	28.7	45	21.5
704	Using unleaded petrol	103	49.3	39	18.7	67	32.1
705	Reducing the number of nuclear bombs in the world	132	63.2	30	14.4	47	22.5
706	*Planting more trees in the world	157	75.1	25	12.0	27	12.9
707	*Generating electricity from wind and waves	141	67.5	30	14.4	38	18.2
708	*Using recycled paper more	163	78.0	16	7.7	30	14.4
709	Protecting rare plants and animals	90	43.1	63	30.1	56	26.8
710	*Saving electricity	115	55.0	37	17.7	57	27.3
711	Reducing starvation in the world	75	35.9	81	38.9	53	25.4
712	*Not using cars as much as now	134	64.1	32	15.3	43	20.6

Notes: \* = scientifically accepted answers

## V. DISCUSSION

Studies on students' understandings of the GHE started about 30 years ago [1][5][9]. Yet, the research findings show that Bruneian students nowadays still hold naïve conceptions about this environmental issue. The students defined GHE as a natural phenomenon such as ozone layer depletion and air pollution. Confusion on GHE and ozone layer is one of the most widely reported alternative conceptions reported in the previous studies [1][4][5][17]. Aksan and Çelikler [19] also documented that even student teachers erroneously linked GHE with the thinning of ozone layer and air pollution. The students in the research also defined GHE as global warming. In terms of natural and anthropogenic GHE, the students did not have informed knowledge about the advantages of natural GHE. Consistent with the findings by Gautier [17], students were unaware that natural greenhouse gases warm the Earth, and enhanced GHE causes global warming.

Similar to the study by Boon [8], high school students in this study had naïve ideas on eight out of twelve greenhouse gases. The greenhouse gases which were less known to the students were nitrous oxide, methane, ozone and water vapour. The findings of this study supported the previous findings which found that water vapour was the least known greenhouse gases among students [20]. The students mistakenly identified sulphur dioxide as one of the greenhouse gases. It was found that students had a propensity to relate the greenhouse gases with the air pollution. From their point of view, gases causing pollution would also lead to the occurrence of GHE.

From the aspect of the GHE mechanism, the students were confused about the mechanism of the GHE. They did not have informed knowledge on the types of radiation and wavelengths, as well as the emission and entrapment of heat in the atmosphere. They also did not understand the role of the atmosphere in allowing radiation with different wavelengths to enter the Earth. The findings of this study were parallel the previous

studies. Hansen (2003 as cited in Schreiner et al.[20] summarized that students were confused about heat transmission, reflection, absorption and emission. Shepardson et al. [2] also found that students did not have sufficient knowledge about infrared radiation and its radioactive forcing.

From the aspect of causes of the GHE, a high percentage of the students were well-informed that the presence of excessive carbon dioxide, burning of fossil fuels and deforestation and methane would result in the GHE. This finding was consistent with the results of previous studies carried out on the students from different grades [9][21]. Similar to the previous studies [9][21], less students appreciated the ground-level ozone as a contributor to the GHE. They also held the misconception which were found to be prevalent among high school students, including rubbish-dumping, sun's rays, radioactive wastes, acid rain and holes in the ozone layer contributed to the GHE[9][20][21].

Compared to the causes of the GHE, the students had more informed views on the consequences of the GHE. They study shared the same ideas with the students from the United Kingdom and Turkish [4][9][21][22] concerning the two repercussions of intensified GHE which were climate change and ice-melting at the Poles. One of the most common misunderstandings among the students was that the GHE would cause skin cancer [3][4][9]. Students believed that ultraviolet entered the Earth through the holes in the ozone, causing a rise in the temperature and at the same time, resulting in more skin cancer cases [7][9].

The findings were in agreement with the results of the previous studies [1][9][21] which found that students understood the contribution of tree planting, reduction of car use and use of recycled paper in reducing the GHE. The students did not appreciate the contribution of nuclear power in reducing the GHE. Francis et al. [1] suggested that the majority of the students believe that nuclear was harmful and destructive to human beings, so nuclear might not help to mitigate the GHE. In fact, nuclear energy might be able to fill the gap between carbon-based and renewable energy sources [23]. Students in the present study might not be familiar with the nuclear power stations as Brunei has not yet developed this alternative energy. Although students had learned that nuclear resources are one of the green energy sources in Year 7 Science syllabus, their unfavoured opinions towards the nuclear power stations were obvious. The students also believed that using unleaded petrol and reducing the number of nuclear bombs could mitigate the GHE. Boyes and Stanisstreet [9] argued that students might think that unleaded petrol was more “environmentally-friendly” and was more useful in “greening” the environment than the leaded petrol.

## VI. CONCLUSION

GHE appears to be indiscernible and complex to individuals [1][9][20]. To understand this issue, students need to understand some abstract science concepts such as the absorption and the re-emission of the electromagnetic rays at different wavelength, as well as the relationship between the infrared radiation and the GHE[12]. Furthermore, the interrelatedness between some environmental issues such as the GHE and global warming gives greater challenges to educators to discuss these issues in classrooms [24]. Since some of the causes of varies environmental issues are similar and overlap [1], students can easily develop “experiential gestalt of causation”, where they provide common explanations and reasons for different science concepts.

This research advances understanding of the students’ alternative conceptions about the GHE. As the details about the GHE, including its mechanism and types of greenhouse gases are not thoroughly discussed in Bruneian high school curriculum [14][15][16], teachers can develop teaching materials to expand students’ knowledge about this phenomenon. Curriculum materials including textbooks, and electronic devices should be reviewed and designed based on students’ alternative conceptions to help them learn environmental issues.

Besides, teachers should provide supplementary materials for students, developing their interpretations and reasoning abilities [25] of intangible natural phenomenon. As environmental education focuses on an integration of knowledge, values, attitudes, and practical skills, assessments should be designed carefully to

provide a clear picture for students about what they need to achieve after the lessons. Only then they will put in concerted effort to unearth the underlying premises of the environmental issues.

The current study has a few limitations. Since the current study did not collect any qualitative data about the students' choices for Question 3 to Question 7, their reason for choosing a certain item remains in a black box. Further studies can collect qualitative data through student interviews to understand the reasons underlying their responses and sources of their knowledge about the GHE. The results of the study show that the students held a lot of vague beliefs on the GHE. These non-scientific views will definitely impinge on their future study of other environmental issues. However, the source of the students' misconceptions was not identified. Future research can be done on identifying the barriers of teaching and learning about the GHE in classrooms. Both teachers and students can be the targeted group in such studies to address hindrances of learning this topic from different perspectives. Future research can also focus on initiating students' conceptual change concerning the GHE. It is important to identify students' existing knowledge, stimulate them with cognitive conflicts and clear up their confusion through creative teaching strategies. Efforts should be put in to investigate the effectiveness of more authentic teaching approaches such as utilization of technologies and out-of-school experiences to promote conceptual change in students.

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