Secondary Students' Concepts of Global Warming

This study explored secondary students' concepts of global warming. Students from three schools in Indiana and Michigan participated in the study. The 51 students were from grades 7-12. The study used an open-response questionnaire which students responded to in writing and/or drawing. The questionnaire consisted of 6 items addressing the following concepts: (a) evidence of global warming, (b) relationship between atmospheric CO2 level and global warming, (c) impacts of global warming, (d) greenhouse effect, (e) causes of and resolutions to atmospheric CO2 rise, and (f) the water cycle. Student responses were content analyzed using an inductive approach. The following summarizes our interpretation of the students' concepts of global warming.

Q		Categories	Reason/explanation	Number of students according to grade levels					Summary
				7th (N=23)	8th (N=16)	10th (N=2)	11th (N=7)	12th (N=3)	
1		(Graph: the change in temperature and CO_2 over the past centuries) How do you think these data support scientists' view that the climate is warming?							
		The graph supports scientists	Based on the theory of greenhouse	2			1		a. Most of students answered based on graph b. Several students explained greenhouse effect theory to answer the question, but not mentioning about the graph c. Most of students (36/51 respondents) tried to explain relations between temperature and atmospheric CO2 rising d. Less than half students (21/51) found that increasing CO2 level leads to rising temperature e. Every student who referred greenhouse theory in their answer said that rising CO2 leads to temperature rising
			Based on the graph (fact)	16	16	2	5	2	
			Link between the graph & theory	3					
			Rising CO_2 leads to temperature increasing	9	7	2	3		
			Rising temperature leads to CO_2 increasing	4					
			Both temperature and carbon dioxide level follow each other		6		1		
			Not mentioning the correlation between CO_2 and temperature	8	3		2	2	
		N- support					1	1	
		Do not know		2					
	A	If there were no increase in CO_2 levels, would our climate change?							
		No change	Based on the graph of temperature and CO_2		4				a. Less than half (23/51) students thought that CO_2 control can stop climate change b. About 38 % of the students who said "rising CO_2 leads to temperature increasing" (see Q1) supported CO_2 control to stop climate change c. Students (26/51) who did not trust CO_2 control argued various causes of climate change. (But, there was no consistency) d. Most (18/26) of them (who said Yes) thought other atmospheric gases (besides CO_2) would cause climate change
			Based on the greenhouse effect theory	10	4		2	1	
			Because CO_2 has no effect on climate change	2					
			Due to ozone depletion making atmosphere thinner	1					
			Due to ozone letting more sun & ultraviolet rays	1					
			Chemicals (pollutants) in the air		2	1	2	1	
			Burning fossil fuel				1		
			Oxygen	1	2			1	
			Nitrogen		1				
			Water vapor				1		
			Other greenhouse gases		2	2			
			Other gases in the air	1	1				

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2	B	Yes (Climate would still change due to)	Thickness of the atmosphere			1				e. Particularly, 6 students attributed climate change to air pollution; 4 students to Oxygen; 4 students to other greenhouse gases; 2 students to other gases in the air; 2 students to ozone layer; one student to nitrogen; one student to water vapor
			Polar ice cap and US		1					
			Rotation & revolution of the earth		1					
			Tilt of earth			1				
			Radiation in the air			1				
			Moving continent / plate tectonics			1		1		
			Collision with meteor or other unknown reason		1					
			Our body		1					
			Plants		1					
			Trash					1		
			Temperature		2			1		
			Ice ages				2			
			Global warming				2			
			Change of air moving					1		
			Natural temperature change (not mentioning any specific factor)		1					
		No answer/ Do not know			2					
3		Some scientists think that Earth's climate is getting warmer. If they are correct, what will happen to……?								
	A	Ocean	No change (the amount of sea water is controlled by water cycle)			1				a. Almost every student thought sea water would get warmer b. But, the students predicted the different results of warmer sea water, from sea level rise/decrease to chemical changes of water c. The most students (29) expected sea levels would rise due to melting polar ice(26 students) and increased precipitation(3 students)
			Sea levels rise	due to melting polar ice	13	4	2	4	3	
				due to increased precipitation	2			1		
			Sea levels decrease	because warming makes water shrink				1		
				because water get hotter	1					
				because warmer weather causes people to drink more water		1				
				because evaporation increases	1	2				
			Sea levels stay same	by balance between ice melting and evaporation of ocean				1		
			warmer		1	6				
			More evaporation		3	5				
			More precipitation		2	2				
			Warmer ocean causes more rain in coastal area		1					
			Overflowing ocean causes major floods			2				
			Rising temperature increases DO level in the water			1				
			Rising temperature increases CO_2 level in the water (based on the graph of CO_2 and temperature)			1				
			Saltier	because of more evaporation		1				
				because more salt is dissolved		1				
			No answer/ do not know		3					
				shorter winter and longer summer	3	3		1		a. Most of students (46/51) thought weather would get warmer
				warmer/hotter (days/seasons)	6	1	2	2	2	

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3	B	Weather	Getting warmer	No/less snow	5	6		2		b. But, results of warmer weather that students thought were various, like more/less precipitation and humid/drier c. Relatively many students (24 students) expected no/less snow and more precipitation/rain. d. There was no student who forecast different climate changes according to the location of an area
				more precipitation/rain	5	7		1	1	
				More humid	1	1			1	
				Less rain & getting drier	1	2		3		
				More hurricanes/tropical storms	4			1		
				more evaporation	1	1				
				No more extreme cold weather or tundra		1				
			Be colder & flooding					1		
			Big change of temperature (drop or rise)		1					
			acid rain by chemical exhaust			1				
			No answer/ do not know		2					
	C	Plants & animals	No change		1					a. Most of students (50/51) expected the global warming would result in changes to plants and animals b. Most students (39/51) supposed the changes to wildlife would be very serious like death /decrease in number (compared to the probable effects on human and society; see 3-D) c. The most common answer (13/39) was that many would die from warmer/hotter weather d. Some students thought the changes to wildlife would be different, depending on... - whether they are plants or animals (15 students), and - where they live like latitude and land/water (12 students) e. Five students expected chained results through interrelationships (e.g., food chain) between plants and animals in ecosystem
			Have more water, but less land						1	
			Some like the warmth; others do not		3					
			Have a hard time	because of heat	1					
				because of environmental change				1		
			Need to adapt to more heat			2				
			will adapt to the changes			1	2	1		
			Only some will survive through adaptation					2		
			Change of variety		1					
			Plants thrive	with more sun rays, letting animal have more food	1					
				by year-round growing; but extreme hot weather will be hazard	1					
				but, animal should migrate	1					
			Plants would die	from less rain	1					
				from too much sunlight		1				
				from hot weather	1					
				with polar animals because they cannot move northward	1	1		1		
				leading to death of animal	1	1				
			Aquatic lives will thrive	because of increased habitat	1					
				because of increased ocean temperature		1				
			Aquatic lives will die	due to increase in temperature	2	1				
				due to increased DO		1				
				due to lack of drinking water	1					
				due to increased CO_2 level in the water		1				
			Many would die	from warmer/hotter weather	6	5		1	1	
				from drier weather		4				
				from flooding	1	1		1	1	
				from climate change				2		
				from loss of habitat	2	1				

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				causing the earth to lose oxygen					1	
			Animals would die from flooding		1					
			Animals living in cold climates moves to north, eventually die/ but, those from warmer climate would thrive		1					
			Animals would suffer from lack of oxygen, because plants store more CO_2, cutting down Oxygen;			1				
			Tropical plants die, leading to starving of herbivores; but good for carnivores having more to eat (dead herbivores)		1					
			No answer/ do not know		2					
3	D	People & society	No change / overcome (with technology/ some resolutions)		4	3	1	4		a. Most students (33/51) thought some changes would happen to people and society b. However, the most common answer (14 students) was that there would be no change to people and that society or people can resolve the problem c. Smaller number (12/51) of students expected death of people as a result of global warming, compared to the number of students (39/51) who supposed death of plants of animals d. Some students (11) concerned about the effects on food, clothing, housing and job e. Some students (4) expected people would try to resolve the problem
			Oxygen will decrease in amount, but science would resolve the problem			1				
			Change (not elaborating answer)				1	1		
			Try to adapt to the warmer weather		1					
			Need to be adapted to living in water					1		
			Try to resolve the problems	Attempt to change what is happening	1					
				Use less gas in winter, and more air conditioning in summer		1				
				People will take more caution on using fossil fuels	1					
				People will stop using gas producing cars	1					
			Effects on job, food, clothing, housing, etc	Some lose jobs related to snow or winter		1				
				Needs to buy new supplies (e.g., clothing) according to changed weather		3				
				Transportation change (fewer places accessible by land)	1					
				More chances of food spoiling due to hotter temperature		1				
				Shortage of food (due to less plants and animals)		1		1		
				Move to another region because of climate change	3				1	
				Have less land/ lose home near the ocean				1	2	
				Fight for land (many part of land flooded)	1					
			Less social activities of people because people would like to stay inside in hotter weather			1				
			More skin disease with more sun light			1				
			People will die	(not mentioning reasons)					1	
				from flooding	1	2				
				from hot weather	1	2		1		
				because people cannot breathe due to increased CO_2	1	1				
				from lack of drinking water (due to no rain/ dry weather)	2	3				
			but, people still would be able to get water from underground		1					
			No answer/ do not know		6					
		Draw and explain your understanding of the greenhouse effect.								
			Identifying CO_2 as a greenhouse gas		9	2		1	1	

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4	A	Scientific concept	Identifying water as a greenhouse gas						1	a. Only thirteen students named the specific kinds of greenhouse gases (i.e., most of students (38/51respondents) did not identified any kinds of greenhouse gases) b. However, most of them (12/13) identified only CO_2 as greenhouse gas; only one student (1/14) mentioned about water vapor as well c. Also, small portion of students (17/51) identified infrared radiation which is re-emitted by the earth surface or clouds back into the atmosphere; only one (1/17) called it "infrared radiation" d. Most of students (37/51) were not able to identify the role of greenhouse gases e. Most of students knowing the role of greenhouse gases also identified infrared radiation which is absorbed by greenhouse gases, although it was usually expressed only in drawing, rather than statements f. Students who know the existence of long-wave radiation going out of the earth also held other important basic concepts on greenhouse effect g. Some students (14) drew greenhouse gases or atmospheric gases as a layer
			Identifying infrared radiation re-emitted by the earth surface/clouds back to the atmosphere (in drawing)		9		1	5	2	
			Also, calling it "infrared" radiation				1			
			Identifying the role of greenhouse gases		7	3	1	2	1	
			Identifying long-wave radiation which is emitted upward to the space, keeping the heat balance of the earth		2	1	1	1	1	
			Identifying sources of CO_2 emission (car, factory), but not natural sources		3		1			
		Students' concepts	Knowing existence of greenhouse gases, but not their effect		2					
			No identifying any specific kinds of greenhouse gases		14	14	2	6	2	
			Identifying only CO_2 as greenhouse gas		9	2		1		
			Plants produce CO_2 for human to breathe			1				
			Drawing greenhouse gases (e.g., CO_2) as a layer		6		1	2		
			Drawing atmospheric gases as a layer (in high level of the sky)		2	1		1	1	
			A layer of gases prevents warm air from mixing with cooler air					1		
			A layer of CO_2 gases acts as an insulator, keeping heat inside of the earth (not absorbing and re-emitting mechanism)		4					
			Sun rays/hot air get trapped in the atmosphere (not mentioning about greenhouse gases)		3	2			1	
			Ultraviolet rays directly heat up the earth		1		1		1	
			Only part of sun rays can get through into the earth atmosphere		1					
			Radiation keeps heat from going back out (confused between greenhouse gases and radiation)			1				
			Confused between ozone layer and greenhouse gases/atmosphere	Infrared radiation is trapped by ozone layer				2		
				Holes in a layer of atmospheric gases let sun rays come into the earth	1				1	
			Glass of greenhouse absorbs/magnifies the sun rays			2				
		Describing mainly (not earth greenhouse effect)	Greenhouse effect by glass of it (not earth greenhouse effect by greenhouse gases)		1	10				
			Greenhouse (not greenhouse effect)		1					
			Photosynthesis (not greenhouse effect)			2				
			Air & water pollution (not greenhouse effect)			1				
			End of the world		1					
			Flooding		1					
			Air moving in atmosphere					1		
			Ice melting		1					
			Save the whales		1					
			How to save electricity to prevent global warming		1					
		No answer & drawing/ do not know			1			1		

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4		Drawing	Earth greenhouse effect only	10		2	4	3	h. Two students drew both earth greenhouse and greenhouse, comparing/contrasting them
			Greenhouse effect only	1	10				
			Greenhouse only (not greenhouse effect)	1	2				
			Earth greenhouse effect (comparing with greenhouse)		1		1		
			Greenhouse (comparing with earth greenhouse effect)		1				
			Both (comparing/ contrasting between them)	1	1				
			Both (not comparing/contrasting between them)	1	1				
			Incoming sunlight (part of which can come into the earth atmosphere)	1					
			Thermometer/graph showing rising temperature	2					
			Just sun, clouds, trees, plants, and land				1		
			Ice melting in south pole	1					
			Flooding	1					
			End of the world	1					i. The most common source of learning about greenhouse effect was school/science class (22 of 33 respondents of the question), and then TV
			Save the whales	1					
			Air & water pollution (not greenhouse effect)		1				
			The way how to save electricity to prevent global warming	1					
	B	Source of learning	school/ science class/ text book	7	8		5	2	
			parents	1					
			workers		1				
			TV (weather channel, news, scientific documentary, movie, etc)	5	3				
			Book/ study		1		1	1	
			Experience in greenhouse		2				
			Guess	1					
			No answer	11	4	2	1		
		(Graph: the change in CO2 levels at the Mauna Loa Observatory in Hawaii) List and explain the natural processes and human activities that might cause the CO2 levels to change, and resolution to lower it.							
		Natural processes	Photosynthesis of plants	1	2				a. Relatively common answers were temperature change (9/51), volcanic eruption (9), and breath of animals/people (8) b. Nine students (who thought temperature change would have effects on CO_2 rising) were likely to be confused about correlationship between temperature and CO_2 level c. Many answers were hard to make direct connections to CO_2 level change, which are humid weather, water, water cycle, precipitation, wind, sun, atmosphere, greenhouse effect, hurricane, rotation of earth, etc
			Plants produce CO2		1				
			Breath of animals	1	2			1	
			Breath of people	2	5			1	
			More animals	1					
			Less trees	1	1				
			Increasing population	2	2				
			When plants die and are decayed	1					
			Increased amount of sunlight increases plants growth, causing CO_2 level to drop		1				
			CO_2 cycle		1				
			Temperature change (increase/decrease)	2	4	1	1	1	

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5	A	Natural processes	Humid weather		1					d. Some students (5) talked about problems in Hawaii. It is likely that these students do not understand what is a baseline of CO_2 level e. Some students (11) might not be able to distinguish between natural processes and human activities
			Water					1		
			Water cycle			2				
			Precipitation						1	
			Wind					1	1	
			Sunlight/ rays					1	2	
			Scattered sunlight/ heat					2		
			Forest fire		1	3		3		
			Atmosphere				1			
			Volcanic eruption				1	2		
			Volcanic eruption	producing CO_2	3	1	1			
				causing no plant to grow		1				
			Greenhouse gases			1				
			Greenhouse effect						1	
			Thin air allowing CO_2 to expand			1				
			More hurricanes		1					
			Rotation of the earth			1				
			Temperature increase in Hawaii		2	1				
			Increasing visitors in Hawaii, causing more fires		1					
			Mot enough plants in Hawaii		1					
			Deforestation		2	2				
			Producing CO_2		1					
			Pollution					1	1	
			Cars, Planes, Chemical plants or factories		2	2				
			No answer /do not know		5			2		
	B	Kinds of human activities	Deforestation		2	6				f. The most students attributed increase of CO_2 levels in atmosphere to motor vehicles (30/51) and factory (25/51) g. Some students might think human activities which are supposed to be harm to the environment would also increase CO_2 level, like polluting (15/51), CFCs(2/51), construction of building (2/51), and littering (1/51), which do not likely have direct connections to CO_2 level change. However, these students could have more complicated concepts to connect between them, so it cannot be said that they are wrong only with this data. h. Most of answers appear to be from students' daily life (very specific), rather than theoretical answer like burning fossil fuel
			Car/ plane/ boat		14	5	2	6	3	
			factory		10	10		4	1	
			Heater/air conditioner		1	2				
			Tourism		1					
			Constructions of houses, factories, parking lots			1				
			Producing chemicals (pollutants)/ Smoking		5	5		3	2	
			CFCs		2			1		
			Human induced forest fire			2				
			Fires					1		
			Burning wood			2				
			Waste of energy			1				
			Nuclear energy			1				
			Littering (decomposition of trash)			1				
			Physical activity (surf, skate, running, etc)		2					

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5			Materialism		1				i. The most popular resolution were related to car and factory j. Environmentally positive actions, in general, were identified as resolution to lower CO_2 level
			Breath of people	3	4				
			No answer/ do not know	5			1		
	C	Resolution	Plant plants/trees	2	3				
			Cut down less trees		3				
			Less fires		2				
			Stop building new houses and factories		1				
			Reduce CO_2 emission and increase stuffs taking it	1					
			Limit the usage of gas heaters		1				
			Use car less/ carpool/ ride a bike or walk/public transportation	7	2	2	4	2	
			Make/ buy/ drive (solar energy, electric) cars not using fossil fuel	6	3				
			Reduce the number of chemical plants (factory)/limit the output (production)/ Set filters (technologies to clean the air) on factories	3	4		1		
			Use energy saving materials	1	1				
			Use electricity less	1					
			Change to non-spray things	1					
			Stop littering		1				
			Reduce pollution	1	5		2	1	
			Recycling				1		
			Do not burn garbage	1					
			Do not burn things that is not wood					1	
			Do not burn so much fuel				1		
			Do not start fire				1		
			Breathe less / walk instead of run	2					
			Cool down the weather		2				
			Nothing can do	1					
			Not sure	1					
			No answer/ do not know	5					
		Draw and explain your understanding of the water cycle.							
		Components of scientific concept	Solar energy	11	8	2	3		a. Most of students identified solar energy, clouds, precipitation, and evaporation as essential components of water cycle
			Clouds	18	15	2	6	2	
			Condensation	2	4	2		2	
			Precipitation/ rain	21	14	2	6	3	
			Evaporation	21	12	2	6	3	
			Transpiration			2			
			Transportation (of water vapor/clouds)				3		
			Surface runoff	1	6		3	1	

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6	A		Infiltration	1			3	1	
			Stream flow	4	5		1		
		Students' concepts	Not link to topography	2	1	2			b. Many students (36/51) thought water cycle or evaporation occurs over a body of water
			Water cycle occurs over a large body of water	13	7				
			Water cycle occurs over a puddle	1					
			Evaporation occurs over a large body of water	4	6	1	2	2	c. Some students thought evaporation occurs only in daytime (8 students) or by heating of sun (8)
			Water cycle occur in the area with big mountain and big water (in drawing)	1	1				
			Evaporation occurs only in daytime	4	1	1	2		
			Evaporation occurs by heating	2	4	2			
			Clouds take up water from the earth	2					
			Precipitation only as a form of rain	16	12		6	1	d. Most of students (35/51) identified only rain as precipitation
			Confusing between precipitation & evaporation		1				
			Confusing between condensation & precipitation		2				
			Confusing between condensation & evaporation	1					
			Water -> plants grow -> Produce oxygen		1				
			Trees store water		1				
			Draw and describe air pollution which causes greenhouse gases	1					
			Draw and describe water purification system	1					
	B	Source of learning	School / (Science) class	12	13		6	3	e. The most common source of learning about water cycle was school/science class (34 of 45 respondents of the question), and then science book and study
			Science book	2	1		1		
			Study	2	1				
			Much heard about it	1					
			TV (discovery and geographic channel)	2					
			Everyday experience			1			
			No answer	4	1	1			