Climate Change? Who Knows? A Comparison of Secondary Students and Pre-service Teachers

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Abstract: In the context of recently published academic discrepancies between Queensland students and students from other Australian states, final year pre-service teachers were surveyed to explore their understanding and knowledge of climate change. Their responses were compared to those of secondary students to discern any significant gains in knowledge as a consequence of tertiary teacher training.
Responses from a survey completed by a sample of 107 pre-service teachers and 310 grade 10 secondary students were examined for their level of understanding and knowledge, models of explanation and sources of information of the phenomenon.
Results showed similarities between the two groups, with knowledge and understanding of climate change remaining unacceptably low in pre-service teachers, including those secondary specialists citing science and environmental studies (SOSE) as their focus of study.
The study highlights the need to develop tertiary science curricula to bridge pre-service teachers' knowledge and understanding gaps of important school curriculum topics while embedding these in broader considerations of curriculum planning.

Between December 2008 and April 2009 an independent review of literacy, numeracy and science standards in Queensland primary schools was conducted at the behest of the Queensland Premier Anna Bligh (Masters, 2009). Findings showed that, in all subject areas, Queensland students up to grade 10 perform less well than their counterparts in New South Wales, Victoria and the ACT, with more pronounced differences in mathematics and science. Another issue of concern was that, amongst Queensland students, there was a disparity between those living in metropolitan areas and those living in regional and rural areas, with the latter having lower average levels of achievement.

Masters (2009) concluded that one of the ways improved outcomes in literacy, numeracy and science standards could be facilitated is through "access to a workforce that is very well prepared through pre-service teacher education programs"(p.vii). Masters (2009) also stressed that:

> As well as meeting threshold levels of pedagogical content knowledge in literacy, numeracy and science, it is important that beginning teachers have sound levels of knowledge themselves in these areas. Concerns have been expressed to this review about some beginning teachers' own levels of competence and confidence in mathematics and science… (p.ix)

Reported in this paper are the findings of a project conducted to examine the understanding and knowledge of the greenhouse effect and ozone depletion, issues underpinning climate change, from a sample of 107 final year Bachelor of Education pre-service teachers attending a regional university in Queensland. These topics were chosen because of their political

and scientific currency and frequent media coverage. It is not unreasonable to believe that if individuals engage with these topics lifestyle and political decision changes might follow. Bronfenbrenner (1979) termed issues such as climate change macrosystem issues because of their widespread implications at national, local and individual levels. Macrosystem issues affect economic, policy and cultural norms. Boyes and Stanisstreet (1993) stated that the greenhouse effect has been cited as "perhaps the most important and widely reported problem in recent times" (p.531).

Evidence of climate change due to human activity, particularly the combustion of fossil fuels since the industrial revolution, has been collected for some years. "Global Greenhouse Gas emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004" (IPCC, 2007, p.4). Consequences of higher average temperatures due to the greenhouse effect such as rises in sea level, desertification, extinction of plant and animal species, shifting of agricultural patterns and increased frequencies in extreme weather phenomena such as cyclones are now considered unequivocal evidence by the scientific community (IPCC, 2007) with very few divergent views (e.g., Khilyuk & Chilingar, 2003).

Until recently, the Australian government, supported by industry lobby groups such as the coal producers, demonstrated little inclination to adopt policies to mitigate our carbon footprint, meeting with modest opposition from the public (Lowe, 2000). Before the election of the new federal government in 2007, failure to ratify the Kyoto Protocol sent mixed messages to the community (Papadakis, 2002), possibly influencing pedagogical strategies at all levels of education. Lately, however, there has been a change in governments in the US and Australia followed by a stance reversal on climate change. Media in Australia are increasingly reporting scientific research about climate change. The message that is coming forward now is one urging immediate action to avoid a human catastrophe (Oxfam, 2009). The call to take action however, does not merely involve policy; it also requires public support. One way to secure public support is by providing unambiguous information about the issues involved to all levels of the community, a view endorsed, ironically, by sceptical political figures such as Senator Fielding (Rodgers, 2009). This is especially important for current and future generations who will be most affected by climate change and whose lifestyle will have to be considerably and, preferably, willingly altered to mitigate their carbon footprint. The teaching profession is thus poised as a key player in this process and in the well-being of our planet.

The National Curriculum Board of Australia ratifies this perspective by stipulating that climate change and adaptation will be taught as part of the science curriculum from primary through to secondary years (Commonwealth of Australia, 2009). It is in the context of Masters' (2009) findings in Queensland and the broader Australian community's acknowledgement of climate change support that the question arises "what do current pre-service teachers in Queensland understand about the basic science of climate change, formerly referred to as the greenhouse effect, so that they can meet their students' needs in the classroom?" The aim of the research is to take findings into account in the future design of tertiary curricular materials for the Bachelor of Education course in Australia, to emulate the "Greening of the curriculum" movement occurring in Europe ((Junyent & Ciurana, 2008).

Previous Research

Many studies have focused on ways of understanding and thinking about global warming. These studies described ways of conceptualising the greenhouse effect and the ozone layer depletion. These sometimes conflated phenomena are poorly understood by US college students (e.g. Kerr & Walz, 2007; Morgan & Moran, 1995; Wilson & Henson, 1993) and UK college

students (Jeffries, Stanisstreet, & Boyes, 2001; Spellman, Field, & Sinclair, 2003) while Australian college students have an inadequate understanding of the role of the ozone layer (Cordero, 2001).

Teachers' and prospective teachers' ideas have also been examined (i.e. Boyes, Chambers, & Stanisstreet, 1995; Dimitriou, 2002; 2003; Dove, 1996; Groves & Pugh, 2002; Khalid, 2001, 2003; Koulaidis, Christidou, & Brossman, 1994; Papadimitriou 2004; Summers, Kruger, Childs, & Mant, 2000), the results showing that teachers also hold misconceptions and misunderstandings about climate change (i.e. Dove 1996; Groves & Pugh, 1999). Examples of prevalent misconceptions include the following: that global warming is caused by increased penetration of solar radiation, that it is connected with holes in the ozone layer, that it would result in increased skin cancer, and that use of unleaded petrol would reduce it. Across most groups examined, there appeared to be a general conflation of thinking about global warming and ozone layer depletion.

These misconceptions and misunderstandings were probably due to, among other things, the complexity of the science involved and until recently the controversy and personal attention, by way of mitigating actions, these issues demanded. Given that there is empirical evidence that suggests pro-environmental behaviour is predicted by knowledge and education about the issue in debate (Barr, 2007; Weaver, 2002), it is important that prospective teachers, who are in a position to influence their students, begin their teaching careers with a clear understanding of at least the basics of a topic as important as climate change.

Sample and method

A sample of 107 final year pre-service teachers participated in this study. Of those, 56 were primary education specialists (PRI) , 32 early childhood education specialists (ECE) and 19 secondary education specialists (SEC) of whom 8 cited science or studies of the environment and society (SOSE) as an area of expertise.

A survey (Appendix 1) was used to elicit participants' understanding and knowledge of climate change by examining their knowledge and ideas of the greenhouse effect and the ozone layer, the sources of their knowledge and the actions they were prepared to undertake to mitigate their carbon footprint. This survey has been used previously to examine secondary school students' knowledge of these topics (Boon, 2010).

Current pre-service teachers have experienced, in the main, the same science curricula at school as current secondary school students, since the new National Curriculum has not yet been implemented in Australia. This means that prior to their university course they may or may not have been taught about the greenhouse effect and ozone layer at school. Queensland students attending state schools at the present time should be exposed to both phenomena to a degree by the end of grade 10. However, this is not always the case as individual Queensland schools are free to select content material for their work programmes to provide "learning experiences and assessment tasks through which students have opportunities to demonstrate what they know and can do in the Years 1–10 Science key learning area" (QSA, 1999, p.8). The strands within the Science key learning area in Queensland are: science and society; earth and beyond; energy and change; life and living and natural and processed materials (QSA, 1999). Climate change also appears in the Key learning area "Studies of Society and Environment (SOSE)", in the core strand Place and Space, (QSA, 2000, p.41). All of the pre-service teachers at the university where this study took place were graduates of Queensland schools.

The science component of the training that pre-service teachers receive in the university where this study was conducted depends on their specialisation: secondary specialists of science have science content training delivered by the science faculty while primary and early childhood education specialists receive science training within the education faculty.

In order to ascertain whether these pre-service teachers have experienced teaching about climate change additional to what they might have received at secondary school, their understanding and knowledge about these issues was compared with results from a sample of regional Queensland secondary students. Both groups were surveyed using the same questionnaire (Appendix 1). A total of 310 grade 10 students from four state schools selected at random in a Queensland regional city initially completed the survey in the final months (November /December) of the school year of 2007.

Pre-service teachers from the same regional Queensland city as the secondary students were surveyed in June 2008, just after the change of federal government in Australia. The 107 final year students participated voluntarily, with a participation rate of 68%. The rest of the final year cohort opted not to participate or were absent from the lecture when the survey was administered.

The completion of the questionnaire was anonymous and voluntary and both secondary students and pre-service teachers were free to leave unanswered any questions that they did not want to answer. The questionnaire (Appendix 1), comprising a range of multiple choice as well as longer, open response items, was completed during regular science classes with the students' usual science teacher. A total of 15 classes in grade 10 participated in four schools, reflecting an 80% participation rate, providing a wide cross-section of ability.

Results from the secondary teacher specialists are excluded from the comparisons and examined separately. This is because it is assumed that science and SOSE specialists will know that they will be required to teach elements of climate change to their students. It is thus expected that they would exhibit superior knowledge and understanding when compared to other secondary specialists.

Research questions examined and compared and contrasted secondary students with final year pre-service teachers for:

A. Their knowledge of climate change, its causes and consequences.

B. Conflation of ideas between climate change and the role played by the ozone layer.

C. The sources of their ideas.

The following question was included for pre-service teachers only by way of further insight into their thoughts about the importance of climate change

D. The range of actions pre-service teachers are prepared to undertake in response to climate change.

The secondary specialists' results are reported separately in all instances.

Results

The SPSS 14 programme (SPSS, Chicago, IL) was used to perform all statistical procedures.

Table 1 presents a summary of all results obtained through questions 1-7, by group, (secondary students and pre-service teachers, excluding secondary specialists), including chi square tests (χ^2) of independence and their significance.

		Secondary students		***Pre-service teachers PRI/ECE***		***Pearson's Chi***	***P***
Question	***Response categories***	***N***	***Column %***	***N***	***Column %***		
Been in a greenhouse?	No	219	71.3%	34	38.6%	31.8	0.001
	Yes	88	28.7%	54	61.4%		
Warmer or cooler in greenhouse?	Don't Know	115	37.5%	14	16.3%	18.8	0.001
	The same	11	3.6%	0	.0%		
	Cooler	54	17.6%	20	23.3%		
	Warmer	127	41.4%	52	60.5%		
Why is it hotter in a greenhouse?	traps light or heat	43	13.9%	22	25.0%	47.8	0.001
	humidity	21	6.8%	6	6.8%		
	other light incorrect reason	4	1.3%	2	2.3%		
	cooler- incorrect	14	4.5%	8	9.1%		
	gases heat up greenhouse	4	1.3%	0	.0%		
	plants affect temp inside greenhous	9	2.9%	8	9.1%		
	insulation/ type of greenhouse materials affect temp.	18	5.8%	10	11.4%		
	glass magnifies sunlight	2	.6%	0	.0%		
	don't know	181	58.4%	20	22.7%		
	uv implicated	2	.6%	0	.0%		
	ventilation effects	12	3.9%	12	13.6%		
Main Greenhouse Gases	Oxygen	28	9.3%	0	.0%	9.2	0.05
	Nitrogen	19	6.3%	4	4.7%		
	Carbon Dioxide	255	84.4%	82	95.3%		
How does the greenhouse effect affect climate?	don't know	137	44.2%	20	22.7%	143.7	0.001
	partially correct explanation	155	50.0%	14	15.9%		
	correct	18	5.8%	54	61.4%		
Other greenhouse gases	incorrect	278	89.7%	64	72.7%	16.3	0.001
	correct	44	14.2%	14	15.9%		
Sea levels	Don't know	21	6.9%	10	11.4%	4.9	NS
	Stay the same	11	3.6%	0	.0%		
	Fall	43	14.1%	12	13.6%		
	Rise	230	75.4%	66	75.0%		
Rainfall	Don't know	34	11.2%	10	11.4%	1.9	NS
	Same in most places	8	2.6%	2	2.3%		
	Higher in most places	44	14.5%	10	11.4%		
	Lower in most places	61	20.1%	14	15.9%		
	lower in some, higher in others	156	51.5%	52	59.1%		
Sunshine	Don't know	31	10.1%	2	2.3%	9.0	NS
	The same in most places	33	10.8%	12	13.6%		
	More sunshine	145	47.4%	38	43.2%		
	Less sunshine	19	6.2%	4	4.5%		
	more in some, less in others	78	25.5%	32	36.4%		
Farmer's crops	Don't know	46	15.1%	16	18.2%	6.6	NS
	Stay the same	12	3.9%	2	2.3%		
	Generally better	19	6.2%	0	.0%		
	worse	228	74.8%	70	79.5%		

Ice caps	Don't know	21	6.9%	0	.0%	9.4	0.05
	Stay the same	5	1.6%	4	4.5%		
	Get bigger	12	3.9%	2	2.3%		
	get smaller	267	87.5%	82	93.2%		
Burning oil or coal	Don't know	34	11.2%	2	2.3%	7.4	0.05
	decrease	20	6.6%	4	4.5%		
	increase	249	82.2%	82	93.2%		
Planting trees/forests	Don't know	25	8.3%	0	.0%	8.5	0.05
	Increase	34	11.3%	8	9.1%		
	Decrease	243	80.5%	80	90.9%		
CFC's	Don't know	138	46.8%	16	18.2%	23.2	0.001
	decrease	15	5.1%	8	9.1%		
	increase	142	48.1%	64	72.7%		
Alternative energy sources	Don't know	36	12.0%	0	.0%	11.7	0.001
	Increase	38	12.7%	12	13.6%		
	Decrease	226	75.3%	76	86.4%		
Insulating buildings	Don't know	78	26.0%	6	6.8%	18.0	0.001
	Increase	46	15.3%	10	11.4%		
	Decrease	176	58.7%	72	81.8%		
Using motor cars	Don't know	38	12.7%	2	2.3%	8.7	0.05
	decrease	26	8.7%	6	6.8%		
	increase	236	78.7%	80	90.9%		
Ozone layer	No	25	8.3%	0	.0%	7.8	0.005
	Yes	275	91.7%	88	100.0%		
What does the ozone layer do?	Incorrect answer	146	61.1%	52	59.1%	0.24	NS
	approx. correct answer	38	15.9%	16	18.2%		
	correct	55	23.0%	20	22.7%		
School as a source	Ticked	258	100.0%	48	100.0%	NA	
Parents	Not-ticked	173	56.0%	66	76.7%	12.1	0.001
	Ticked	136	44.0%	20	23.3%		
TV	Not-ticked	94	30.4%	14	16.3%	6.8	0.005
	Ticked	215	69.6%	72	83.7%		
Radio	Not-ticked	234	75.7%	54	62.8%	5.7	0.05
	Ticked	75	24.3%	32	37.2%		
Books/Magazines	Not-ticked	179	57.9%	36	41.9%	7.0	0.005
	Ticked	130	42.1%	50	58.1%		
Friends	Not-ticked	220	71.0%	42	48.8%	14.7	0.001
	Ticked	90	29.0%	44	51.2%		
Internet	Not-ticked	155	50.2%	50	58.1%	1.72	NS
	Ticked	154	49.8%	36	41.9%		

Table 1 Answers to questions 1 -7 by group, showing tests for independence

Results indicated that both groups were equally uncertain about the greenhouse effect, with only 13.9 % of the secondary students and 25.0% of the pre-service teachers invoking trapped heat or "light" as the cause of the heat inside the greenhouse (p <.001). Pre-service teachers were more likely to know about the higher temperature inside a greenhouse than secondary students, perhaps because of greater personal engagement with information about climate change, rather than knowledge of the science behind the greenhouse effect. This explanation seems likely because differences between groups about *what is the greenhouse effect* showed similar rates of correct/incorrect conceptions. Both groups had fewer than 15 percent correct responses (Table 2), showing a very low rate of understanding of the science of the greenhouse effect.

Explanations of "what is the greenhouse effect?"	*Secondary students*	*Pre-service teachers PRI/ECE*
	%	%
Correct	14.1	11.4
Don't know	30.1	22.7
Warming of the climate	14.4	12.5
Warming due to ozone layer	13.0	22.7
Gases affecting ozone layer		
Hole in ozone layer causing warming		
Caused by carbon dioxide	1.0	0
Gases insulating the earth	12.4	11.4
Others (ventilation/shade cloth/materials)	4.5	3.4
Media hype	4.5	0
Pollution	6.0	15.9

Table 2 Percentage and type of model of explanation used about the greenhouse effect by group

When asked about other greenhouse gases, a very low percentage of students or pre-service teachers knew gases besides carbon dioxide such as CFCs, nitrous oxides, methane, or water vapour. This additional information suggests that their knowledge of the greenhouse effect is fragmented and derived from informal sources, such as the media. What is of particular interest is that there appears to be a higher proportion of pre-service teachers, 22.7% compared with 13.0% of secondary students, confusing the role of the ozone layer with the greenhouse effect, possibly reflecting uncertainty in the way they were taught at school by previous generations of teachers.

A notable difference between the two groups was their appreciation of *the connection between the greenhouse effect and climate change*, with a higher proportion of pre-service teachers acknowledging the connection between the greenhouse effect and climate change (61.4% pre-service teachers compared to 5.8% secondary students, Table 1).

Assessment of the question about human activity and its impact showed that groups performed equally on what might happen to farmers' crops, rainfall, sea levels and sunshine levels. But there were statistically significant differences between the groups' knowledge on the questions about the ice caps, burning fossil fuels, planting trees, using CFCs, using alternative energy sources, insulating buildings and using motor cars with the pre-service teachers' knowledge consistently better than secondary students' knowledge (Table 1). These differences might reflect pre-service teachers' better grasp of issues related to energy and its economic ramifications, as well as, perhaps, remembering the drive to ban CFCs in previous decades.

Respondents' qualitative explanations about why it is hotter inside a greenhouse show a constructivist principle in action, that is, ideas already constructed by the learner facilitating the acquisition and development of new concepts (Driver, Asoko, Leach, Mortimer, & Scott, 1994), since their explanations link with their everyday experiences. Secondary students' ideas reflect their inexperience with glass greenhouses (Table 1) (71.3% said "no"), compared to a larger number of pre-service teachers who said that they had been in a greenhouse (61.4%). Nonetheless, both groups constructed their explanations with more familiar ideas derived from living in Queensland. Ideas such as humidity, insulation materials, and plant action to raise temperatures in greenhouses (which some students thought were made of green material that attracted more heat) were frequently espoused. A lack of experience with outdoor experiments using sunlight and glass prisms/ magnifying glasses, could be a reason for the small response rate of certain explanations (categories: traps light or heat, other light incorrect, glass magnifies sunlight). A notable finding is that no explanation about *what is the greenhouse effect* was offered exclusively by one group (except for "media hype"), suggesting that the pre-service teachers had not been exposed to additional explanatory models about the greenhouse effect at tertiary level. The category "caused

by Carbon dioxide" is deemed to be simply incomplete data offered by secondary students. The explanatory models students use to express their ideas about the greenhouse effect are listed in Table 2.

Explanations are remarkably consistent, with the use of more general explanation models in some instances (warming of the climate, pollution), while secondary students' apparently more limited knowledge of the hole in the ozone layer makes a smaller contribution to their construction of understanding of the greenhouse effect (13%) when compared to pre-service teachers (22.7%). The appearance of "Media hype" in their explanation might signify engagement with the political stance that Australia had hitherto undertaken on the matter, given that they completed the survey about six months earlier than the pre-service teachers. This answer is a clear illustration of Bronfenbrenner's (1979) macrosystem influences percolating through to local school levels. Of particular interest is that the questions "*why is it hotter inside a greenhouse*" and "*what is the greenhouse effect*" did not elicit parallel or comparable answers in either group. For example, humidity is cited as a reason for the greater temperature inside a greenhouse but this explanation is not offered as the cause of the greenhouse effect. Furthermore, in some cases respondents reported that it is cooler inside a greenhouse while this was never cited as a response for *what is the greenhouse effect.*

Conflation of ideas about the ozone layer and the greenhouse effect appears to persist in both groups. Student comments about the function of the ozone layer (e.g. it keeps the air inside the planet; protects the earth's surface from extreme heat from the Sun; keeps all the gases and oxygen inside the earth; it is a blanket around the Earth) suggest that they have an idea that it protects the Earth from something important, though what that is, is unclear in most students' minds. Pre-service teachers' responses were, overall, very similar to those of the secondary students and included the addition of some unreasoned answers. For example:

- stops light from passing through the atmosphere,
- it's a layer of gas that protects the earth from dangerous gases,
- keeps gases around the globe,
- makes up our atmosphere,
- creates Earth's atmosphere-oxygen-gravity,
- protects the earth from greenhouse gases,
- keeps weather close to earth at a level which humans can live otherwise Sun's heat will burn Earth.

The question that is difficult to answer from these results is to what extent each groups' understanding of the greenhouse effect is the basis of their knowledge of climate change. Given their lack of general understanding of the greenhouse effect and knowledge of greenhouse gases coupled with their conflating ideas about the greenhouse effect and the role of the ozone layer, it is not unreasonable to assume that their knowledge of climate change is not linked to their understanding of these phenomena.

The information sources the groups cited varied in predictable ways (Table 1).Only school and the internet as a source, were equally subscribed to by both groups. Important differences between the two groups were friends and parents as sources of information with secondary students citing parents more often while pre-service teachers cited friends. Of note is the result for school, showing all participants cite it as an information source for these issues. As might be expected, results suggest that although television still plays an important educating role for pre-service teachers, the internet has now gained primacy for secondary students, replacing books and magazines as sources of information for them. Such results illustrate the importance of accurate public knowledge of these important issues since as Bronfenbrenner theorised (1979) macrosystem influences have ramifications at the level of the individual.

Differences between secondary and other specialist pre-service teachers' perceptions were also examined (Table 3). Given their small sample number (N= 19) these results are to be

cautiously interpreted. One interesting observation is that those who specialise in either science or SOSE were less likely to state "Don't know" when questioned about whether it was *warmer or cooler inside a greenhouse, what the greenhouse effect is*, and *what the ozone layer does* (Table 3). On the other hand, their responses were not reflective of a higher level of understanding of these issues, with results being comparable to those whose specialist areas were unrelated to science or the environment. This poses a significant problem since, if they were taught about these topics at university, they clearly either did not retain the knowledge or did not understand the science. Perhaps they are not sufficiently interested to retain these issues? If they were not taught about these topics at tertiary level, the question is why not?

Survey questions		***Other Secondary specialists (N=10)*** ***%***	***SCIENCE or SOSE (N=9)*** ***%***
Warmer or cooler in greenhouse?	Don't Know	20.0	11.1
	The same	.0	.0
	Cooler	30.0	22.2
	Warmer	50.0	66.7
Main Greenhouse Gases	Oxygen	.0	.0
	Nitrogen	20.0	11.1
	Carbon Dioxide	80.0	88.9
Other greenhouse gases	No/Don't know	55.6	66.7
	Methane	11.1	.0
	Carbon Monoxide	.0	11.1
	CFC's	.0	.0
	Nitrous Oxide	.0	.0
	Multiple correct answers	33.3	11.1
	Multiple answers	.0	11.1
What is the greenhouse effect?	Don't know	40.0	.0
	Correct	10.0	22.2
	Warming due to ozone hole/layer	20.0	55.6
	Gases insulating the earth	10.0	.0
	Pollution	.0	11.1
	Other/ventilation /shade cloth/	10.0	.0
	Warning of climate	10.0	11.1
Ozone layer	No	14.3	.0
	Yes	85.7	100.0
What does the ozone layer do?	Incorrect answer	50.0	55.6
	Don't know	20.0	.0
	Approx. correct answer	20.0	22.2
Categories of reason for warmth inside a greenhouse	Traps light or heat	33.3	33.3
	Humidity	11.1	11.1
	Other light incorrect reason	22.2	.0
	Cooler- incorrect	11.1	.0
	Plants affect temp inside greenhouse	11.1	11.1
	Insulation / type of material affect temp.	.0	11.1
	Glass magnifies sunlight	.0	11.1
	Don't know	11.1	22.2

Table 3 Secondary pre-service teachers' responses

The range of actions pre-service teachers were willing to take to mitigate their carbon footprint were consistent with general knowledge with few illustrations of specific scientific knowledge of the effects of climate change. For example, the impact climate change is expected to have on water availability and health ramifications was not apparent in their proposed actions.

Typical responses included: use less energy, switch off unused light bulbs/appliances, walk more, car pool, recycle, reuse, educate in schools, live a "clean" life, be more environmentally friendly, use less processed food, protect flora and fauna and the like.

Of interest were a few disconcerting comments which indicated scepticism, being overwhelmed and disempowered or being genuinely confused. For example:

- The obvious reduction of fossil fuels and greater use of 'green' energy. Is global warming not just a natural geological process that we have minimal impact on anyway?? (primary specialist)
- Learn more- information is power! (primary specialist)
- Not sure, the issues seem so large that as teachers all we can do is educate to prevent any further problems; (early childhood education specialist)
- Die! (secondary specialist, vocational education major)

Discussion

The context for this study was provided by Masters (2009), whose report about the attainment of Queensland school students showed they were lagging behind other Australian states. One of his recommendations to ameliorate the situation was to ensure that teachers were trained to a sufficiently high standard, in order to meet the needs of their students, in both knowledge and pedagogy. To this end, the study, centred in a regional Queensland city, investigated pre-service teachers' knowledge and understanding of climate change, an important scientific and environmental issue facing society and mandated in the new National Curriculum. The investigation compared and contrasted pre-service teachers' ideas with those of secondary students to discern whether pre-service teachers were better informed about these important scientific issues.

Results suggest that while there are statistically significant differences between the two groups in their knowledge of the impact of the greenhouse effect upon the climate, main greenhouse gases and other greenhouse gases, with more pre-service teachers being knowledgeable in these areas, there are no significant differences in their understanding of the science of the greenhouse effect and the ozone layer's function. Both groups seem to be equally under-informed (disinterested?) about these important phenomena. Since the areas in which pre-service teachers demonstrate greater knowledge than school students are not areas that require conceptual understanding of greenhouse science, but merely greater engagement with media reports about climatic change, results imply pre-service teachers have not been given additional training in these topics at tertiary level. Results suggest this is the case even for those specialising to teach science and SOSE at secondary level.

It is likely that the picture obtained from this study is not an isolated one. Palmer (2008) conducted a large investigation to document current practices in initial teacher education programs in Australia and found: "In about one-third of the undergraduate primary programs, all the courses were Education offerings and there was no direct involvement of the Science faculty. In these programs, Education staff delivered all of the content" (p.173). It might be argued that knowledge of science content does not predict effective pedagogy for teaching science at primary level (Lloyd, Smith, Fay, Khang, Wah, Lee , L., & Sai,1998). Nonetheless, it seems the alternative: little knowledge or understanding of specific science topics, cannot be held to be desirable either for students at school, or pre-service teachers. Two choices would face newly qualified teachers in such a scenario: either, in order to deliver the curriculum, they would need to spend additional time to learn the material, with perhaps no help from collegial sources, adding stress to their already tight classroom workload, or they would skip the teaching of a challenging topic. It seems from these and other findings (Howitt, 2007) that the latter course has been followed.

The picture gathered from the small sample of secondary specialists' surveys (science and SOSE), though precluding generalisation, suggests that pre-service teachers are either not exposed to these topics in science faculties or that they are not sufficiently engaged with them to recall them. A possible explanation here might be the public debate and dissemination of these topics in the media or on the internet, leading individuals to dismiss their importance. However, this explanation does not seem likely because questions pertaining to *the greenhouse effects upon climate* and *the effects of human activity upon carbon dioxide emissions* were adequately understood by pre-service teachers of all specialisations.

Possible overall explanations of findings in both groups include:

a) Although some can understand the physics behind radiation absorption, the more complex interactions between chemical reactions and physical processes taking place in the atmosphere are difficult to assimilate.
b) Both groups have difficulty remembering material that they have been taught.
c) Both groups simply misunderstand the processes of the Greenhouse Effect.
d) The Greenhouse Effect has been inadequately covered at school/university as a whole process.
e) Both groups are reiterating incomplete information which they may have heard from diverse sources such as the media.
f) A combination of all of the above.

While recall difficulties cannot be excluded, the similarities between the two groups' responses suggest they misunderstand the greenhouse effect as a whole and/or that they have been insufficiently or inadequately exposed to these ideas at school, leaving them with snippets of information gathered elsewhere, which in the case of the pre-service teachers they have not had a opportunity to develop with further training.

The former is illustrated by the models of explanation students report. The same models have persisted over the years with results echoing those found by previous researchers (e.g. see review Lee, Lester, Ma, Lambert & Jean-Baptiste, 2007; Boyes, & Stanisstreet, 1993; 1997). Whilst both groups' answers are qualitatively similar, ideas about the ozone layer's implication in the greenhouse effect seem to have decreased quantitatively in the secondary cohort. A proportion of students now say gases are insulating the Earth. However, to what extent this is the result of a lack of general knowledge about the ozone layer's function rather than a use of new models is not clear. Both groups appear to believe that pollutant gases are responsible for creating the greenhouse effect, a finding encountered in other studies with pre-service primary teachers (Papadimitriou, 2004). These findings might show trends in general public misconceptions (Dunlap, 1998) or an imprecise use of language, reflecting the notion that pollution causes a range of environmental problems. "Media Hype" was proposed by 4.5% of secondary students as another explanation of the greenhouse effect, probably showing political and media influences, macrosystem ramifications, upon secondary students prior to the new government's endorsement of climate change.

A particularly important finding evidenced in both groups was that their explanations for the local effects of warmth in a greenhouse were not extrapolated to be used as explanations of the greenhouse effect in the atmosphere, indicating the relatively low level of connection or application of knowledge across contexts. Of concern were some of the highly unreasoned explanations given by pre-service teachers in response to *the ozone layer's function*. These indicate a very low engagement with science as a whole since they illustrate confusion of various science principles with atmospheric physics/chemistry. For example, "the ozone layer creates Earth's atmosphere-oxygen gravity".

It seems that the construction of students' explanations have not been modified in light of better scientific awareness of the phenomena over the last few decades, a perhaps understandable state of affairs, given the constantly evolving nature of the science behind climate change. For example, it was recently shown that the ozone layer's health, affected by the levels of

Chlorofluorocarbons (CFCs), and nitrogen oxides, can in turn affect the amount of carbon dioxide absorbed by the ocean's phytoplankton because it allows greater concentrations of UV radiation which damages phytoplankton, great atmospheric carbon dioxide "sinks". It can also influence the up-welling of carbon rich ocean currents, due to complex stratospheric cooling patterns which affect winds patterns right down to sea level, making the oceans more acidic, in turn reducing the amounts of atmospheric carbon dioxide that can be absorbed by the oceans (Reilly, 2009). This very new science which, ironically, might give grounds for the conflation of the ozone layer's role and the greenhouse effect, is not described in standard texts and certainly has not been systematically taught except perhaps in specialist tertiary courses. It cannot account therefore for the persistent and generalised conflation of ideas that is observed about the ozone layer's function and the greenhouse effect.

Both groups unanimously cited school as a source of their ideas but one cannot discount the possibility that other factors have influenced their conceptual understanding and engagement with these matters. First, television and the internet may present data on climate effects without explanations of the science behind the phenomena. Droughts, floods and hurricanes may be simply depicted as results of climate change. This is not an unreasonable assumption given the complexity of the science of climate change (Kerr & Walz, 2007; Schreiner, Henriksen, & Kerkeby Hansen, 2005). Second, the perceived urgency of climate change also shapes public engagement with it. As Stanwell-Smith (2007) contends, "One of the many difficulties in getting to grips with climate change is the inevitably long-term projections. 2080s - not many of us that bothered; 2050s - still a long way off; 2011 - now you've got our interest" (p.3). Perhaps disengagement due to the perceived remoteness of the effects of climate change underscores some responses, and in the case of pre-service teachers, an indifference to pursuing an independent understanding of these matters, whether or not they constitute part of their teacher preparation courses. Studies point to situational influences upon students' beliefs and engagement with climate change (Uzzell, 1999). By contrast, a small minority of pre-service teachers' comments showed clearly that they felt climate change was a hopeless situation; that might also have led to disengagement.

In Australia, until recently, there has been a long period of denial expressed by the government regarding climate change; a view that was a reflection of the dominant US stance. The Bush Administration had suppressed action on global warming world-wide, questioning compelling scientific evidence showing that the Earth is heating up because of anthropogenic greenhouse gas emissions (Walsh, 2008). The extent to which that impacted upon Australian secondary and tertiary teachers' pedagogy, curriculum and values has not been examined. Since studies indicate that knowledge about the causes of global warming predicts people's behavioural intentions (e.g., O'Connor, Bord, & Fisher 1999), it is not unreasonable to assume that the manipulation of key scientific reports about climate change could have been responsible for the low engagement of science teachers, pre-service service teachers and tertiary educators with regard to climate change science. This is underscored by Waters-Adams (2006): "ideas, beliefs, and values have all been recognized as integral elements of (teacher) action" (p.920) and Bronfenbrenner's theory (1979) which has been substantiated by a large volume of empirical studies showing macrosystem influences permeate through all levels of society.

There is empirical evidence from diverse countries that teacher understanding of the greenhouse effect is inadequate for teaching it (Boyes & Stanisstreet, 1992; Dove, 1996; Fortner, 2001; Hansen, 2003; Papadimitriou, 2004). This presents a challenge to teacher training institutions worldwide, to spend more time teaching science content to pre-service teachers and to employ pedagogy that is most conducive to student (pre-service teacher) engagement (Lyons, 2005). Taking a constructivist approach requires teaching to be built upon the learner's existing knowledge and their frames of reference. Successful engagement of learner interest is enhanced by the relevance of the topic to the learner.

There is now consistent political acceptance of the causal links between global warming and increased greenhouse gas emissions and support for policies to mitigate these effects. Climate change involves more than science, though the science alone makes it an exciting vehicle for teaching and illustrating physical, chemical and biological concepts meaningfully. It is a rich, authentic, context which brings together societal, economic and affective strands. As Groves and Pugh (2002, p. 381) point out "complex global environmental issues involve much more than 'straight science'—the socio-political concerns involved can be ignored neither by scientist nor by educators."

The current observed drive towards sustainability education and "Greening of the tertiary curriculum" (Junyent & Ciurana, 2008) might go some of the way towards increasing pre-service teacher's engagement with, and confidence to teach, science through issues such as climate change. In this way some of Masters' (2009) concerns and recommendations might be seamlessly addressed. Tan (2009) urges however, that sustainability education should be taught under the banner of science. He states several reasons for this, including "…environmental degradation has been the 'collateral damage' of the progress of science and technology; educators need to acknowledge at least the intellectual responsibility (but not necessarily culpability) and refuse to participate in 'business as usual'" (p.36). Over the years, science curriculum planning has been influenced by various imperatives including the need for ecological sustainability (Carter, 2005), also one of the drivers of "Greening of the tertiary curriculum" movement (Junyent & Ciurana, 2008). The nexus between science and education for sustainability is therefore evident.

A big picture perspective suggests pre-service teacher curriculum planning needs to be embedded in ethical considerations of education and of the role of the teacher. Tan (2009) contends that it must be guided by questions like: "(i) What is the nature of society that we are educating for? (ii) What possibly different kind of society do we have in mind with the intended curriculum innovation? (iii) What forms of knowledge are in/ex-cluded, and why? "(p.33) because, as Young (2008) asserts curriculum is a "social and political construct reflecting particular sets of interests, beliefs and values" (p. 2). Tan's view embraces Freire's (2000) support for critical pedagogy to empower the learner, the teacher being the instrument of this empowerment. Such a view goes beyond "topping up" teachers with more knowledge, though pre-service teacher tertiary curricula should not neglect this aspect. Moreover, to engage the learner at tertiary, secondary and primary levels, and help them make the links between education, culture, human agency and identity Bussey (2008) supports Freire in the context of sustainability education by stating that teachers need to embody the stance they take in the educational arena in their own lives. Perhaps the governmental stance reversal on climate change will have observable ramifications in this area in the next few years.

The pertinence of climate change is increasing as more world scientists urge governments and individuals to take action. Coupled with Masters' (2009) report to improve the academic attainment of our school students it seems tertiary educators cannot afford to ignore findings of pre-service teacher knowledge gaps in vital school curriculum (science) areas. Action to develop tertiary science curricula links well with the current drive towards sustainability education and "Greening of the tertiary curriculum" (Junyent & Ciurana, 2008). Results such as the ones reported here should inform the development of teacher education programs to ensure future teachers are prepared with the best possible skills to engage and empower their students in a changing world.

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Appendix 1 The survey

We are trying to find out what your ideas are about 'the greenhouse effect, global warming and ozone depletion'. **THIS IS NOT A TEST!**

Please complete the table below by circling the correct answer

Do you identify as Indigenous? Yes/ No

(Pre-service teachers ONLY; what is your specialisation: ECE/PRI/SEC for; **IF SECONDARY,** what is your specialist area? …)

Gender: M /F

1. a. Have you ever been in a green house on a warm summer's day? Yes /No
   b. Do you think it is warmer or cooler inside a greenhouse than outside?
      Warmer, cooler, the same, don't know
   c. Can you think of any reason why this should be so?
      Please write your ideas in the space provided

Scientists say that the climate is slowly changing and that this is caused by 'the greenhouse effect'. It is known that some gases in the atmosphere are responsible for the 'greenhouse effect'.
They are called 'greenhouse gases'.

2 a) Which of the following do you think is the main 'greenhouse gas'?
   oxygen, carbon dioxide, nitrogen

2 b) Do you know any other 'greenhouse gases'? Please write them down.

3. a) What do you think the 'greenhouse effect' is? Write down your ideas.
   b) How does it affect the climate? Write down your ideas.

4. What do you think the effects of a warmer climate will be?
   a) The sea levels will……. Rise, Fall, Stay the same, Don't know
   b) Rainfall will be…….. Higher in most places, Lower in most places, Lower in some places and higher in others, The same in most places, Don't know
   c) Sunshine……. More sunshine in most places, Less sunshine in most places, Less in some places and more in others, The same in most places, Don't know.
   d) Farmers crops will be……. Generally better, Generally worse, Stay the same, Don't know.
   e) The ice caps in the North and South Poles….
      Get bigger, Get smaller, Stay the same, Don't know.

5. It is known that human activity produces greenhouse gases. Will the following activities tend to increase or decrease the amount of these gases in the atmosphere?
   a) Burning oil or coal for fuel: increase / decrease/ don't know
   b) Planting trees and forests : increase / decrease/ don't know
   c) Making and using CFCs : increase / decrease/ don't know
   d) Using alternative energy sources such as solar power and wind : increase / decrease/ don't know
   e) Insulating buildings to prevent heat loss/gain : increase / decrease/ don't know
   f) Using motor cars : increase / decrease/ don't know

6. a) Have you heard of the 'ozone layer'? Yes / No
   b) If yes, what do you think the ozone layer does? Write down your ideas

7. Where did your ideas and knowledge to answer this survey come from?
   You may tick more than one source.
   Taught at school
   Parents
   TV
   Radio
   Books/magazines
   Talking to friends
   Internet
   Other
   (Pre-service teachers only)

8. What do you feel you can do to lessen the impact of greenhouse emissions?