Comparing knowledge about greenhouse effect and ozone layer among Norwegian pupils finishing compulsory education in 1989, 1993 and 2005

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Abstract
The greenhouse effect and the ozone layer have been in media's focus more than two decades. In the same period Norwegian compulsory school have had three national curricula. Only the last one prescribes the two topics explicit. During the last two decades media and public debate might have been sources of information causing informal learning among pupils. Changing curricula, formal and informal learning are the background for examining the development of pupils' knowledge about the greenhouse effect and ozone layer from 1989 to 2005. In 2005 the trends seem to be more pupils confuse the greenhouse effect with the effects of the ozone layer. On the same time specific knowledge about the greenhouse effect is improving. The article will discuss some possible causes for the trends, and give some recommendations for teaching the topics.

Introduction
This article deals with five lines of evolution crossing each other in the classrooms of Norwegian schools: The evolution of 1.scientific knowledge about the greenhouse effect and 2.the ozone layer; 3.actions to get control over atmospheric pollution concerning the greenhouse effect and 4.the ozone layer - both heavily reported in media; 5.the incorporation of knowledge about the greenhouse effect and the effects of the ozone layer in the national curriculum for compulsory education. The main focus in the article is the pupils' knowledge about the greenhouse effect and the ozone layer at the time they finish their compulsory education.

The evolution of scientific knowledge about the greenhouse effect has lasted for almost two centuries, here exemplified by some highlights (for a more complete briefing see Houghton, 2004):

- 1827 Fourier claimed that certain gasses in the atmosphere were holding back heat from the earth like the glasses in a greenhouse. This metaphor gave name to the 'greenhouse effect'.
- 1861 Tyndall showed that climate change might be a result of variation in atmospheric carbon dioxide (CO_2) content.
- 1890-ies Arrhenius worried about the extreme burning of coal as a consequence of the Industrial Revolution, and predicted that the average temperature on earth would raise 5-6 degrees if doubling the CO_2 content in the atmosphere. This statement raised a debate on atmospheric pollution.
- 1938 Callender determined that higher content of CO_2 had caused warmer temperatures in America and Europe, and that Arrhenius had underestimated the raise of temperature. Callender and Flohn discussed how the photo synthesis in trees and plants could take up some carbon dioxide and reduce the temperature raise.

- 1941 Flohn wrote an article on human activity as a climate factor.
- 1957 Revelle and Suess worried about CO_2 emission from human activities and argued to monitor changes in the carbon dioxide content of waters and airs as well as the rates of production of plants and animals.

First Arrhenius, then Callender and Flohn, later Revelle and Suess coupled pollution from human activities to a possible climate change. Decades later the evidences were so clear that political action was taken.

Some highlights from the evolution of scientific knowledge about the ozone layer:

- 1879 Cornu postulated that the observed missing ultra violet (UV) part of the sun spectrum could be due to absorption in the atmosphere.
- Hartly discovered that UV-beams could produce ozone (O_3) when passing through air, and meant that this process also could take place in the atmosphere.
- 1912 Fabry and Buisson confirmed Hartly's hypothesis, and estimated the content of ozone equivalent to 5mm (500DU) if sampled at normal atmospheric pressure and temperature.
- 1920 they made better observations and reduced the approximation to 3mm (300DU) – a very good estimate.
- 1924 Dobson used his ever since famous instrument to detect the ozone layer at 40km. (The unit of measurement 'Dobson Units' (100DU=1mm) is a salute to Dobson.)
- 1928 DuPont laboratories invented a compound of different chlorofluorocarbons (CFCs) to be used in refrigerators and industry, and registered the trade name Freon in 1930.
- 1930 Chapman presented the photochemical theory for the ozone cycle in the stratosphere. (It was later clear that the photodissociation of ozone only could explain 20% of natural reduction in the steady state cycle, see 1970)
- 1934 Dobson and collaborators' improved observations showed that the ozone layer is at 22km – a very god result.
- 1970 Crutzen detected the catalytic dissociation of ozone with nitrogen oxides (NO, NO_2) which could explain the remaining 80% of natural ozone dissociation in the ozone cycle. The detection started an international worry about consequences of emission of NO and NO_2 from supersonic aircrafts to the stratosphere.
- 1974 Molina and Rowland published two articles showing that chlorine from CFCs in spray cans and refrigerators are a threat to the ozone layer.
- 1978 U.S. government banned CFCs as propellants in spray cans.
- 1984 a hole in the Antarctic ozone layer was discovered. The news was published in 1985.
- 1986 Solomon launched here theory about heterogeneous reduction of ozone, a major contribution to the explanation of the Antarctic ozone hole, published in 1990.
- 1995 Crutzen, Molina and Rowland won the Nobel price in chemistry, Solomon did not.

After publication of the news about the ozone hole in 1985, international political action was taken almost at once in contrast to the scientific worry about global warming which lasted for decades before coming on the political agenda.

The greenhouse effect and the effects of the ozone layer came both into political and media's focus during the 1980-ies. Some special events sat the scene. The worry about a possibility of increased greenhouse effect and climate change may have started in 1987 with The Bruntland Commission's report *Our Common Future*. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and published the first scientific report in 1990. At UN Conference on Environment and Development (UNCED) in Rio de Janeiro 1992, IPCC's assessment provided much of the impetus for the Framework Convention on Climate Change

signed by more than 160 countries. Like the first one in 1990, the two next IPCC reports in 1995 and 2001 caused considerable public, scientific and political debates all over the world. So did also the long lasting political process ending up with the Kyoto Protocol in 1997, and all following-up sessions of the Conference of the Parties to the Climate Convention up to now. Worry about the increasing energy consumption causing increasing carbon dioxide emissions in both industrial and some developing countries like India and China, are more frequent on the agenda in the 2000-ds than ever.

The public worry about the ozone layer started in 1985 with publication of the news about an Antarctic ozone hole. This event shed light on serious consequences of the use of CFCs. International action was taken, ending up with signing the Montreal Protocol in 1987. The phasing out of CFC-production and use started some years later. Now the concentration of CFCs in atmosphere is no longer increasing. CFCs will be present in atmosphere for over a hundred year. Ever since 1985 media have reported on the ozone holes during the Antarctic spring and more at random on the general ozone depletion. I Norway temporary local low ozone observations followed by an UV-alarm is reported in media almost every spring. The UV-alarm is often connected to worry about a decreasing rate of skin cancer.

During the 1970-ies the foundation for environmental education was established. In Norway *Miljølæreprosjektet* (The Programme for Environmental Education) was implemented in compulsory education in 1971, and the teaching material was in use for more than two decades. *United Nations Environmental Programme* (UNEP) was created by UN General Assembly in 1972, *The Belgrade Charter* setting the general principles for environmental education is from 1975 and *International Environmental Education Programme* (IEEP) started in 1977. The public, scientific and political debates about the future for greenhouse effect, climate and effects of the ozone layer have had impact on the science curriculum in many countries. The first step forward in that direction of environmental education was taken at UNCED (1992) in Rio 1992 by signing *Agenda 21* stating:

> Advancing the role of youth and actively involving them in the protection of the environment… (UNCED, 1992:25.1)
>
> … incorporates the concepts of environmental awareness and sustainable development throughout the curricula (ibid.25.9b).

This is an agenda for action for the environment and development in the 21.century using education and schools as tools for improvement. In Norway the Ministry of the Environment followed up Agenda 21 (ibid.) paragraph about school activities almost word by word (Miljøverndepartementet, 1992:74). In 2002 UN General Assembly voted for the resolution *United Nations Decade of Education for Sustainable Development (2005-2014)* (UNESCO, 2004).

At the test moment in 1989 Norwegian national curriculum *M74* (1974) neither mentioned the greenhouse effect nor the ozone layer. At next test in 1993 the pupils should during lower secondary education have been taught about "changes in the weather and climate … [caused by] human intervention, … spread of pollution." (*M87*, 1987:246, 1990:267) The 'greenhouse effect' was not named. The ozone layer was still not in the curriculum. At the last test in 2005 the curriculum *L97* (1996) prescribed that "pupils should have the opportunity to learn about the greenhouse effect and the effects of the ozone layer" (ibid.:218). This national curriculum was implemented during 1997-2000 and is heavily influenced by Agenda 21, perhaps because Gro Harlem Bruntland (the leader of the Bruntland Commission 1987) at that time was Norwegian prime Minister.

On the background of the scientific, political and educational evolution, the research question is:

> *Has there been any development in knowledge about greenhouse effect and ozone layer among pupils finishing compulsory education during 1989-2005 – with shifting curriculum content and trends in increased media focus as background?*

Methodology

The test in 1989 is the first known on pupils' conceptions of the greenhouse effect and ozone layer (Schreiner, Henriksen and Hansen, 2005). In 1989 greenhouse effect and ozone layer was not in the curriculum, but have moved into media's and public focus during the last years. The questionnaire (table 1) is very simple, containing statements "constructed to detect if the pupils separate the greenhouse effect from the effects of the ozone layer" (translation from Hansen, 1989:22). Many participants in the media and public debate in the late 1980-ies did not distinguish the normal greenhouse effect from the increasing greenhouse effect causing global warming. Many thought that hole in the ozone layer could cause global warming. Which of the atmospheric gasses causing what effects were also very diffuse at that time. These common misunderstandings were used to construct the distractor statements. Exchange or confusing the greenhouse effect with effects of ozone layer is still problems in media, public and political debate (Schreiner et al., 2005). That's why the questionnaire from 1989 could be used in 1993 and even in 2005.

Table 1. Questionnaire about the greenhouse effect given to Norwegian pupils finishing compulsory education in 1989, 1993 and 2005.

Place a cross mark at information about the greenhouse effect which is right at your opinion.

- □ *The greenhouse effect protects us against UV radiation from the sun.*
- □ *The greenhouse effect makes the temperature sink.*
- □ *The greenhouse effect is caused by carbon dioxide gas (CO_2).*
- □ *CFC gas (chlorofluorocarbons) in spray cans and refrigerators may destroy the greenhouse effect.*
- □ *Increased burning of coal, gas and oil increases the greenhouse effect.*
- □ *The greenhouse effect is caused by ozone gas (O_3) in the ozone layer.*
- □ *The greenhouse effect is necessary for life on earth.*

In 1989 and 1993 statement 4 (table 1) was *Freon (CFC) in spray cans and refrigerators may destroy the greenhouse effect* because the product name 'Freon' was much used in media parallel or synonymous with CFC. In 1989 many thought (some still think) that CFCs are used as propellants in spray cans – despite it was banned in most countries some years before (in Norway 1981).

The population is pupils finishing compulsory education (15 years old, grade 10) in 1989, 1993 and 2005. The sample (n=348) in 1989 was from 7 schools in Oslo (capital) and suburbs (Hansen, 1989, 1996:102f) all having M74 as curriculum. In 1993 the sample (n=354) was from the same 7 schools plus from 8 schools in rural districts, all having M87 as curriculum (Hansen, 1996:510ff). The same schools (except one) participated in 2005 (n=440) all having L97 as curriculum. Using the same schools makes testing for significant changes 1993-2005 possible. The samplings however, were done administrative not randomized, which limits the external validity i.e. the possibility to generalize the results to the population. However, the samples are relatively big and from both urban and rural communities all over southern Norway.

Results and discussions

Responses to right greenhouse effect statements

Everyone, including pupils exchange or confusing the greenhouse effect with effects of the ozone layer should respond right to the last statement *The greenhouse effect is necessary for life on earth* - as both greenhouse effect *and* ozone layer is. In 1989 only 23.3% of the pupils agreed with the statement. The reason for the very low response could be that media did not distinguish the normal greenhouse effect from the increasing greenhouse effect. When describing the greenhouse effect it was often in the context of something to worry about, something anomalous: a coming global warming. In 1989 the pupils did not get any corrective from science textbooks written to curriculum M74, and the teachers were not educated to teach such new environmental and scientific problems. Both pupils and teachers had media as their primary information source.

In 1993 the number was still very low (30.5%) despite the fact that the curriculum M87 (1987:246, 1990:267) prescribed teaching about "changes in the weather and climate". The concept 'greenhouse effect' was not named in the curriculum, but was used in the textbooks. The textbooks did also have texts about the ozone problems which was not a theme in the curriculum (Hansen, 1996:286ff). The pupils and teachers had got the tools i.e. correct textbooks. Perhaps the school science discourse was weaker on the new topics than the everyday discourse among lay persons and media, both still not as routine distinguishing the normal greenhouse effect from the increasing greenhouse effect.

The test in 2005 is a significant improvement ($\alpha<0.5\%$) from 1993. 75.0% of the pupils agreed with the last statement *The greenhouse effect is necessary for life on earth.* The cause might bee improved teaching and formal learning. The curriculum L97 was in general more binding and precise than M87. L97 (1996: 218) prescribed that "pupils should have the opportunity to learn about the greenhouse effect and the effects of the ozone layer". The textbooks of course treated the two effects more in depth. From 1992 environmental issues was obligatory subject in teacher education with the greenhouse effect and ozone layer as themes (KUF, 1994:227ff).

Pupils' improvement on the last statement could also partly be caused by better informal learning. Between the tests in 1993 and 2005 there have been a lot of major climate political events all highly media focused: IPCC's reports 1995, 2001; Rio 1992, Kyoto 1997, and the Conference of the Parties every year afterward. Still some research communities are skeptical to IPCC's conclusion 2001: "There is new and stronger evidence that most of the warming observed over the last 50 years is attributed to human activities" (IPCC, 2001:10). Medias' report about the scientific discussions might have trigged the pupils' interest and the teachers teaching about the greenhouse effect. The information in media is year by year being more precise. The worry about global warming, causes and possible consequences are increasing, and they are often on the Norwegian political agenda. Therefore the everyday discourse could have been improved. Despite all good reasons for improvement on the test given in this paragraph, the knowledge *Increased burning of coal, gas and oil increases the greenhouse effect* are on equal level from 1993 to 2005. Perhaps this fact was well known in 1993 already, and "two of three" is near an upper limit. Or more likely, because we don't use coal, gas or oil for production of electrical energy to use in the homes in Norway, so the problem is not so personalized to Norwegian youths.

Improved formal and informal learning could have caused the significant increase from 1993 to 2005 in number of double-responses to the two other right statements about the greenhouse effect (table 2). Neither is 44.5% impressive high, nor the numbers of responses to the two single statements, respectively 57.7% and 66.1%. It is rather disappointing and difficult to explain that the knowledge *The greenhouse effect is caused by carbon dioxide gas (CO_2)* is significantly decreased since 1993.

Table 2. Responses to right greenhouse effect statements (*% response*).
*Significant change (α<0.5%) 1993-2005.

Statements:	1989 n=348	1993 n=354	2005 n=440
The greenhouse effect is caused by carbon dioxide gas (CO_2).	*39.1*	*65.8*	**57.7*
Increased burning of coal, gas and oil increases the greenhouse effect.	*53.2*	*66.7*	*66.1*
Both right greenhouse effect statements marked	29.9	36.7	*44.5
No answer	5.5	5.0	0.0

Responses to incorrect greenhouse effect statements

Four of the statements are distractors i.e. incorrect statements about the greenhouse effect (table 3). Three represented common misunderstandings in 1989 connected to the effects of the ozone layer. They are still common in 2005 (Schreiner et al., 2005). The high response on *CFC gas in spray cans and refrigerators may destroy the greenhouse effect* is perhaps an example of Boyes and Stanisstreet's (1996:37ff) theory of over-generalization:

> … an overview of the results of series of studies of children's ideas about environmental problems such as global warming and ozone layer depletion, their causes and consequences. The results suggest that although children are aware of the consequences of global environmental problems and of a range of pollutants which cause them, their thinking is over-generalised. Children tend to imagine that all pollutants contribute to all environmental problems (Boyes and Stanisstreet, 1996:37)
>
> How children's thinking about the consequences and causes of global environmental problems might be confused by the term 'pollution'." (ibid.:48)

"Synonyms offered for 'pollute' are 'contaminate', 'infect' and 'poison'" (ibid:42), all used in many environmental connections. After the discovery of the ozone hole in 1985, media wrote about Freon as a pollutant destroying the ozone layer. In the 90-ties media turned to use CFCs addressing both the ozone hole and the general ozone depletion. According to Boyes and Stanisstreet's theory, pollution of the atmosphere by Freon and CFCs also may destroy the greenhouse effect. Even today only experts know that CFCs are very potent greenhouse gasses increasing the greenhouse effect, not destroying it.

An "inverted" theory of over-generalization might explain why an increasing number of pupils agree with the statement *The greenhouse effect protects us against UV radiation from the sun.* 'Protect' and other positive terms are the opposite of 'pollute' or 'pollution', and what protecting us against one environmental global threat should then protect us against other threats.

The distractor *The greenhouse effect makes the temperature fall* have a rather low rate of agreement at all tests. This might be explained in three ways. First, many connect the term 'greenhouse' with something 'warm' or 'high temperature' – and will disagree with the statement. Second, in 1989 media and lay persons did not, and some does still not, make a difference between the normal greenhouse effect and the increasing greenhouse effect causing global warming. Global warming means raising temperature, not falling. Third, those who make a difference might know that the (normal) greenhouse effect causes steady average temperature level over years in balance with incoming and outgoing radiation.

According to table 2, more than half the pupils at the two last tests know that *The greenhouse effect is caused by carbon dioxide gas (CO_2)* and two of three know that *Increased burning of coal, gas and oil increases the greenhouse effect.* An overview of the results of series of studies (Schreiner et al., 2005) shows that this is most often the only greenhouse gas pupils know about or could name. Carbon dioxide is responsible for only 21% of the greenhouse effect. The major greenhouse gas is water vapor gas (H_2O) responsible for 68%, hardly known to lay persons today. Ozone (O_3) is responsible for only 6.5% of the total greenhouse effect. In 1989 only experts was aware of the fact that ozone is a minor greenhouse gas. However, many did probably know that ozone in the ozone layer protects us against UV radiation from the sun. This scientific fact was a part of the media information coming along with the discovery of the Antarctic ozone hole in 1985. The years to come the ozone hole in Antarctic, the discovery of a general global depletion and the processes leading to the Montreal protocol in 1987, was well reported in media and was on the political agenda. On that background the statement *The greenhouse effect is caused by ozone gas (O3) in the ozone layer* was in 1989 and 1993 seen as a clear distractor supported by only respectively 14.9% and 17.5%. In 2005 it could perhaps be disputable if the statement is a clear distractor since some informed pupils might know that ozone is a minor greenhouse gas. However, ozone is fare from the *cause* of the greenhouse effect alone. In 2005 almost a quarter of the pupils agreed with the statement, and this is a significant increase from 1993. This result will be further discussed together with the results from table 4.

Table 3. Responses to incorrect greenhouse effect statements (*% response*).
*Significant increase (α<0.5%) 1993-2005.

Statements:	1989 n=348	1993 n=354	2005 n=440
The greenhouse effect protects us against UV radiation from the sun.	*19.8*	*23.5*	**36.1*
The greenhouse effect makes the temperature fall.	*9.8*	*13.0*	*15.7*
CFC gas in spray cans and refrigerators may destroy the greenhouse effect.	*22.7*	*32.5*	**45.7*
The greenhouse effect is caused by ozone gas (O_3) in the ozone layer.	*14.9*	*17.5*	**27.5*

Responses, an overall look

The results in table 4 confirm results from series of international studies (Schreiner et al., 2005) showing that many pupils exchange the greenhouse effect with effects of the ozone layer or confuse facts about the two effects. The tests in 1993 and 2005 show that the number of pupils exchanging the two effects are below 20%. The number of pupils confusing facts between the two effects (responded both to right and incorrect statements) are significant increased from 1993 to a very high level (51.1%) in 2005. The sum of pupils exchanging and confusing the effects is 70.4% i.e. only 30% have not agreed with any incorrect statements at all in 2005, a significant decrease from 50% in 1993.

Table 4. Responses, an overall look of all statements (*% response*)
- except *The greenhouse effect is necessary for life on earth.*
*Significant increase (α<0.5%)1993-2005.

	1989 n=348	1993 n=354	2005 n=440
Exchange greenhouse effect with effects of ozone layer. No right, some wrong responses.	26.4	17.5	19.3
Confuse greenhouse effect with effects of ozone layer. One/two right, some wrong responses.	18.1	32.8	*51.1
Sum of Exchange and Confuse	44.5	50.3	*70.4

Table 3 and 4 shows disappointing results in 2005: A significant increased number of pupils holding single incorrect greenhouse effect statements and confusing the two effects. Three incorrect statements could easily be changed into right statements about the ozone layer by replacing 'greenhouse' with 'ozone layer': *The ozone layer protects us against UV radiation from the sun. CFC gas in spray cans and refrigerators may destroy the ozone layer. The ozone layer is caused by ozone gas (O_3) in the ozone layer.* One possible explanation of the bad results could be that factual knowledge about the ozone layer, like the three "changed" statements, are decreased among lay persons and pupils during the last ten years. This is the ten years spent in compulsory school by the tested 15-years old pupils in 2005. The ozone problems are less often focused in media than in the period 1985-1995. This might be an effect of the good impact on the ozone layer from facing out production and use of CFCs in the name of the Montreal protocol. Good results are not media scoops like the ozone hole, increased ozone depletion, increased number of skin cancer and the political processes years before and after Montreal. While the concern about the ozone layer have more or less faded out from media and peoples minds, the focus on the increasing greenhouse effect, global warming and the causes and consequences have been high on the agenda both in media, in politics and among lay persons in Norway all the last ten years. The pupils' informal learning about the ozone layer has more or less faded out. So has perhaps also the arena for formal learning about the ozone layer, the school. Less media focus might lead to less interest among pupils and teachers. Low interest is pore condition for learning about the ozone layer. At the same time the interest and questioning around greenhouse effect problems have increased, and the teachers might have concentrated their teaching about atmospheric problems in that direction. The result is that the pupils have had problems to see that the distractors (table 3) easily could be changed into right ozone layer statements because they do not have very much factual knowledge about the ozone layer.

Conclusions

Results from discoveries and research on changes in the greenhouse effect and the effects of the ozone layer during the 1980-ies increased the media focus and trigged the political and public discussion about the evidences, results, possible causes and possible consequences. Major international steps towards taking control of the atmospheric problems were taken during the 1990-ties. The themes were stepwise introduced in the science curriculum for compulsory school from nothing in 1974 to explicit learning goals on both topics in 1997. In 1989 only one of four 15-years old pupils did know that the greenhouse effect is necessary for life on earth. In 2005 three of four knew. Both formal learning in school and informal learning from media and public discussions might have contributed to increased knowledge.

From the late 1990-ies the media and public focus on ozone problems decreased thanks to retardation in development of ozone layer depletion. At the same time the focus on increased greenhouse effect and global warming are increased. This double situation might have influenced the teaching and learning in compulsory school in a way that might be the answer to why both factual knowledge about the greenhouse effect and the confuse of greenhouse effect with effects of ozone layer have increased form 1989 to 2005. The confuse could perhaps partly be an effect of pupils tendency to over-generalize environmental problems caused by 'pollution'.

Given the trends and analysis are true, one recommendation for promoting *education for sustainable development* with regards to increased greenhouse effect and ozone-problems might be Boyes and Stanisstreet's old advises:

> The teaching strategy that could address the conceptual problems surrounding the ozone layer will be that characterised by a less holistic approach in which the causes and consequences of different environmental problems [like increasing greenhouse effect] are dissected and teased apart. (Boyes and Stanisstreet, 1995)

Media and The Internet are often setting the agenda for the public debate on environmental problems. A recommendation is to actively use those sources in the teaching of the scientific as well as societal, political, ethical and other aspects of the problems. A last recommendation is to couple the learning of the scientific aspects of environmental problems like ozone depletion and global warming with the pupils' personal attitudes, visions, feelings, engagement, political and practical action:

> Climate education for empowerment involves fostering in young people an integrate understanding of the many aspects (scientific, ethical, political …) of the climate [and ozone] issue, hopeful visions for the future and a conviction that it lies in their power to shape the future. That is a challenge which we as science educators can take up. (Schreiner et al., 2005)

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