Knowledge about the greenhouse effect and the effects of the ozone layer among Norwegian pupils finishing compulsory education in 1989, 1993 and 2005 - What now?

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Abstract
The greenhouse effect and the effects of the ozone layer have been in the media and public focus for more than two decades. During the same period, Norwegian compulsory schools have had four national curricula. The two last-mentioned prescribes explicitly the two topics. Media and public discourse might have been sources of information causing informal learning among pupils. The point of departure for this questionnaire based examination of the development of pupils' knowledge about the greenhouse effect and the effects of the ozone layer from 1989 to 2005 is the changing curricula and formal and informal learning. In 2005 the trends seem to be that more pupils confuse the greenhouse effect with the effects of the ozone layer. At the same time, specific knowledge about the greenhouse effect is improving. This article will discuss some possible causes for these trends, and give some recommendations for teaching the topics in accordance with the last national curriculum implemented in 2006.

Introduction
This article deals with five lines of evolution crossing each other in the classrooms of Norwegian schools:

1. The evolution of scientific knowledge about the greenhouse effect and its effects.
2. The evolution of scientific knowledge about the ozone layer and its effects.
3. The evolution of public awareness and of political actions against atmospheric pollution influencing the greenhouse effect.
4. The evolution of public awareness and of political actions against atmospheric pollution influencing the ozone layer.

All these four aspects of the topics have been increasingly reported in the media since the late 1980-ies. Perhaps the problems of global warming have overshadowed the interest in ozone problems during the last decade.

5. The evolution of the incorporation of knowledge about the greenhouse effect, the effects of the ozone layer and the political actions against atmospheric pollution in the national curriculum for compulsory education.

The main objective of this article is the tests of pupils' attained knowledge about the greenhouse effect and the effects of the ozone layer at the time they finish their compulsory education. The attained knowledge is developed under the influence of all five aspects of the topics and is the result of both formal and informal teaching. The article discusses some possible causes for trends in the knowledge, and gives some recommendations for teaching the topics in the new national curriculum implemented in 2006.

1. The evolution of scientific knowledge about the greenhouse effect has lasted for almost two centuries (for a more complete discussion see Houghton, 2004). In 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'. In the1890-ies Arrhenius worried about the extreme burning of coal as a consequence of the Industrial Revolution, and predicted that the average temperature on the Earth would raise 5-6 degrees if doubling the CO_2 content in the atmosphere. This statement raised a debate on atmospheric pollution. Research the decades to come coupled pollution from human activities closer to a possible climate change. In 1990 The Intergovernmental Panel on Climate Change (IPCC) presented three reports on Climate Change: the Scientific Assessment, the Impacts Assessment and the Response Strategies. The relative clear evidences aroused the media, public awareness and

some politicians. The reports are followed up in 1995, 2001 and 2007. Some limited political actions have been taken, but still very much is to be done to cope with the problems and the effects.

Arrhenius' model was an atmosphere with carbon dioxide (CO_2) as the only natural and anthropogenic greenhouse gas. The gases causing the natural greenhouse effect are water vapor gas (H_2O) responsible for 68% of the greenhouse effect, CO_2 (21%), carbon oxide (CO), methane (CH_4), nitrous dioxide (NO_2), nitrous oxygen (N_2O), ozone (O_3). The Kyoto Protocol (see 3 below) covers anthropogenic contributions to the greenhouse effect from CO_2, and five other gasses (Houghton, 2004, p. 247). Despite being the far most important greenhouse gas, water vapor (H_2O gas) is not included because the direct anthropogenic contribution is minor compared to evaporation from the oceans. IPCC's (2007a, p. 4) last report includes anthropogenic CO_2, N_2O, CH_4 and O_3, plus anthropogenic aerosols in their models.

This highlight from evolution of scientific knowledge does not reflect the complexity of the greenhouse effect and climate system. How these gasses function as greenhouse gasses on molecular level in different bands of the infrared spectrum of terrestrial radiation (Houghton, 2004, p. 19) is not straight forward to teach even if adapted to a secondary educational level. The most difficult part of the topic is perhaps how natural and anthropogenic greenhouse gases influence the climate system. The problem is that pupils and students often lack understanding of essential features of the climate system (Andersson, 2000; Andersson, & Wallin, 2000; Fisher 1996, 1998a, b, c; Hansen 1996 (p. 548), 2003; Koulaidis, & Christidou, 1999). Arrhenius' climate model included only the atmosphere. Today the interchange of energy, momentum and matter between atmosphere, ocean, land, volcano, snow, land ice, sea ice, clouds and the biotic nature make a very complex system (Houghton, 2004, p. 90) with many couplings and feedback systems (pp. 90-95). The natural and increased greenhouse effect affects both the global water cycle (p. 155) and carbon cycle (p. 30). Even in a condensed and popularized version the complex greenhouse and climate system is demanding both for teachers and students in secondary education.

2. The evolution of the scientific knowledge about the ozone layer starts in 1879 when Cornu postulated that the observed missing ultra violet (UV) part of the sun spectrum could be due to absorption in the atmosphere, later coupled to ozone (O_3). In 1920, after years of research, Fabry and Buisson estimated the content of ozone equivalent to 3mm (300DU) if sampled at normal atmospheric pressure and temperature – a very good estimate. During 1924 to 1934 Dobson and collaborators' used Dobson famous instrument to show that the ozone layer is at 22km – also a very god result. (The unit of measurement 'Dobson Units' (100DU=1mm) is a salute to Dobson.)

In 1930 Chapman presented the first photochemical theory for the ozone cycle in the stratosphere, completed by Crutzen in 1970. The last detection started an international worry about consequences of emission of nitrogen oxides (NO, NO_2) from supersonic aircrafts into the stratosphere.

Molina and Rowland published two articles in 1974 showing that chlorine from chlorofluorocarbons (CFCs) in industry, spray cans and refrigerators is a threat to the ozone layer. CFCs were invented by DuPont in 1928 and registered as trade name Freon in 1930. U.S. government banned CFCs as propellants in spray cans in 1978.

A hole in the Antarctic ozone layer was discovered in 1984. The discovery was first published in 1985 and was immediately top news all over the world. Solomon launched her theory about heterogeneous reduction of ozone in 1986, published in 1990. This was a major

contribution to the explanation of the Antarctic ozone holes. Crutzen, Molina and Rowland won the Nobel Prize in chemistry in 1995. Solomon did not.

After the 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 scientific knowledge about the natural ozone cycle in the ozone layer described above (1930, 1970) and the ozone depletion mechanisms (1974, 1986) are intricate, but perhaps not as complex as the greenhouse effect and climate system (see 1 above). It is of course demanding to teach the topic in secondary education even for trained natural science teachers.

3. The greenhouse effect and the effects of the ozone layer came both into political and media focus during the 1980-ies. Some special events set the scene. The worry about the possibility of an increased greenhouse effect and a climate change may have started in 1987 with The Brundtland (1987) Commission's report *Our Common Future*. *The Intergovernmental Panel on Climate Change* (IPCC) was established in 1988 and published the first three reports in 1990. At the 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 IPCC reports in 1995, 2001 and 2007 caused considerable public, scientific and political debate 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 the present time. Worry about the increasing energy consumption causing increasing carbon dioxide emissions in both industrial and some developing countries like India and China, is more frequently on the agenda in the 2000s than ever. The last IPCC (2007a, p. 10) report in 2007 states:

> Most of the observed increase in global average temperatures since the mid-20th century is *very likely* [p>90%] due to the observed increase in anthropogenic greenhouse gas concentrations. This is an advance since the TAR's [IPCC 2001] conclusion that "most of the observed warming over the last 50 years is *likely* [p>66%] to have been due to the increase in greenhouse gas concentrations".

The struggle against increasing greenhouse effect and global warming was not awarded a Nobel Prize until 2007, and then not in physics or chemistry. The Nobel Peace Prize was awarded to IPCC and former Vice President of US Al Gore

> … for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change. (Nobel Foundation, 2007)

In 2006 Gore won an Academy Award ('Oscar') for his documentary film, *An Inconvenient Truth*, discussing global warming and the environment. The events in 2006 and 2007 once again set the problem of global warming on the front pages of the media all over the world, and at the height of the political agenda in Norway.

Bell from New Zealand described in his book The Language of News Media in 1991 how the greenhouse effect and the ozone layer are misunderstood both by the writing journalists and their newspaper readers (as cited in Johnsen, 1996). In Norway Johnsen (1996) analysed Norwegian mass media in 1996 with the same result (my translation from Norwegian): "We know that information about environmental issues are difficult to handle both for lay persons

and journalists. That's why we still can read news papers articles where the ozone hole is the main cause for a warmer climate". Seip, & Fuglestvedt (1996) analysed the Norwegian debate after IPCC's report in 1995. Their conclusions were (my translation): "Media promoted series of erroneous claims about climate research … most of it depends on misconceptions and neglecting of scientific facts". Næss, & Fuglestvedt (1997) found that the scientific uncertainty and disagreement is brought out of proportions in Norwegian media. In IPCC (2007a) Summary for Policymakers the word 'uncertain/-ty' is used 26 times on 18 pages. Some critical voices among policymakers, other politicians and journalists still think (hope?) that the whole IPCC is uncertain and the best way to rule is 'business as usual'.

All IPCC reports have been met by dissidents and critical voices both from academia and from lay persons, politicians and journalists. Academic sceptics are an important part of all science. It is however important to notice that:

> IPCC does not conduct any research nor does it monitor climate related data or parameters. Its role is to assess on a comprehensive, objective, open and transparent basis the latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human-induced climate change, … They should be of high scientific and technical standards, and aim to reflect a range of views, expertise and wide geographical coverage. (IPCC, 2007b)

For instance, in Norway there has been a heavy academic debate after IPCC 2007 on The Research Council of Norway's websites (forskning.no) and in mass media. Several (not climate) researchers are sceptical to the IPCC prognoses models, the uncertainty reported, and not to weight the solar-cloud-climate relationship more in the prognoses. The last claim descends from Svensmark, & Friis-Christensen (1997, 2000), and have been voiced in Norwegian academic and mass media several times since 1997. Their hypothesis was of course analysed by other researchers (for a more complete discussion see Benestad, 2006). IPCC has discussed the hypothesis both in 2003 and in the last report, and found it: "Least certain, and under ongoing debate" (IPCC 2007c, p. 188).

In the PISA 2000 study (Programme for International Student Assessment) 15-year olds' understanding of an authentic newsletter article on ozone and problems related to the ozone layer were investigated. Turmo (2003, p. 56) showed that the results in general are harmonised with the overall results in scientific literacy in PISA i.e. there is a wide difference in and across nations in pupils' interpretation and understanding of the newsletter. No doubt, it is still difficult for teachers and pupils to interpret mass media's report from ozone and climate research and politics.

4. The public worry about the ozone layer started in 1985 with the 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 the signing of the Montreal Protocol in 1987. The phasing out of CFC-production and use started some years later. Now the concentration of CFCs in the atmosphere is no longer increasing. The long lived CFCs will however be present in the atmosphere for a hundred years to come. Ever since 1985 media have reported on the ozone holes during the Antarctic spring and more at random on the general ozone depletion. In Norway temporary local low ozone observations followed by an UV-alarm is reported in the media almost every spring. The UV-alarm is often connected with worry about a decreasing rate of skin cancer.

5. During the 1970-ies the foundation for environmental education was established. In Norway *Miljølæreprosjektet* (The Program for Environmental Education, my translation) 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 scientific, public and political debates about the future for greenhouse effect, climate and the ozone layer have had impact on the natural science curriculum in many countries. The first step forward in that direction of environmental education was taken at UNCED (1992) in Rio 1992 by the signing of *Agenda 21* stating:

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

This is an agenda for action for the environment and development in the 21st century using education and schools as tools for an improvement. In Norway the Ministry of the Environment followed up the Agenda 21 paragraph about school activities almost word by word (Miljøverndepartementet, 1992, p. 74). In 2002 UN General Assembly voted for the resolution *United Nations Decade of Education for Sustainable Development (2005-2014)* (UNESCO, 2004). In Norway the implementation of teaching material dedicated The Decade has just started. Unfortunately this work coincides with the implementation of the new national curriculum, in short *LK06,* in 2006, which might take the focus away from the work with environmental issues. Only the future will tell us if The Decade is really going to be put on the agenda before it is over.

This article presents results from three successive tests of pupils' knowledge about the greenhouse effect and the effects of the ozone layer when finishing compulsory education. At the first test in 1989, the first known published on this research area (Hansen, 1989), the Norwegian national curriculum *M74* (1974) neither mentioned the greenhouse effect nor the ozone layer.

At the next test in 1993 the current curriculum *M87* (1987/1990) had weather and climate as main topic, among other things stating that the pupils should, during lower secondary education, have been taught about "changes in the weather and climate … [caused by] human intervention, … [and] spread of pollution" (p. 246/p. 267). The words 'greenhouse effect' was not named. The ozone layer was still not in the curriculum. The test in 1993 used the same questionnaire as in 1989, supplied with interviews of two girls and boys from each class, teacher questionnaires and textbook analysis. 80.0% of the teachers (n=30) felt 'relatively' or 'absolutely free' from the paragraphs in the national curriculum (M87) when planning their science teaching in general (Hansen, 1996, p. 349). Only 23.3% (p. 350) followed the progress in the textbook, many used textbooks more flexible (40.0%). The main topic weather and climate was attached 'lower importance than average' by 43.4% and 'higher' by 40.0% (pp. 352-353) i.e. the teaching of this main topic might differ very much from teacher to teacher. Both groups followed the textbook closer in this main topic than else because they found it difficult (the subtopic 'changes in the weather and climate' was of course not included in their teacher training). The teachers meant that pupils showed 'low' pre knowledge and 'very low interest' (p. 354) compared with other main topics in science.

In 1993 the far most sold textbook (Hansen, 1996, pp. 306-313) in lower secondary science education was very thin on 'changes in the weather and climate', and did only mention the ozone layer in connection with pollution from the Concord and other supersonic aircrafts. Other textbooks treated the greenhouse effect and the ozone layer a bit more generous (pp. 300-301).

The weak curriculum, weak textbooks, most teachers without deeper knowledge and low priority to this topic, is poor background for teaching and learning about changes in the weather and climate. This facts illustrate that introduction of a new topic on formal curriculum level not necessarily leads to immediate changes in the implementation by textbooks and teachers, and hence not to the pupils' formal learning.

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" (p. 218). This national curriculum was implemented during 1997-2000 and was heavily influenced by Agenda 21, perhaps because Gro Harlem Brundtland, the leader of the Brundtland Commission 1987, at that time was Norwegian prime Minister. The test in 2005 was not a part of a bigger research project like in 1993. Analysis of two very good selling science textbooks supporting L97, shows that both are fare better than the M87-versions on this topic. Both are covering natural and increased greenhouse effect, global warming, ozone layer, ozone depletion caused by CFCs, UV-radiation and risk of cancer. One of the teacher guides to the textbooks informs about common misconceptions among pupils (with unnamed address to Boyes, & Stanisstreet (1992, 1993), see below). Both guides have many good ideas how to teach this complex topic.

A demanding and precise curriculum, far better textbooks and some teachers with better knowledge, is a better background for teaching the topic, however, the teachers' priority to this topic is unknown.

The test in 1989 (Hansen, 1989) is the first known on this topic, the next is Boyes, et al. (1992) who refers to IPCC's first report (see 1 and 3 above) on the increased global warming: "Clearly, education about such major issues is of considerable importance". To find the status presence of students' conceptions of the problem, they wanted to design a closed questionnaire. To do so they used 6 open-form questions about the greenhouse effect to a group of English 13/14-years-old (n=60) (described in detail in Boyes, et al., 1993). From the findings they designed 36 statements to be responded on a five point scale. As many as 64% of first year undergraduate students agreed with the statement "The Greenhouse Effect is made worse by holes in the ozone layer". The authors suggested that the students think in the following manner: "Holes in the ozone layer contribute to global warming because they allow increased penetration of solar heat". 51% agreed with "If the Greenhouse effect gets bigger more people will get skin cancer" and 51% agreed with "The Greenhouse Effect can be made smaller by using unleaded petrol". On the other hand, many agreed with right statements as well. The years to come Boyes and Stanisstreet used their questionnaire on large groups, often with co-writers, at different ages and in different countries. An almost universal finding is the confusion between global warming and ozone depletion. Boyes, Chambers, & Stanisstreet (1995) suggested that a reason for this widespread misconception is that learning in this area cannot be experimental. This may be an important point; however, some physical processes essential to this complex area of knowledge (like transmission, reflection, absorption and emission of different wavelengths of electromagnetic radiation) could be illustrated through student experiments or teacher demonstrations (Hansen, 2003; Papageorgiou, & Tsiropoulou, 2004). Pupils and students' confusion between the climate issue and the ozone issue (as well as other environmental issues like radioactive pollution or acid rain) has also been described

by other researchers for almost two decades, for a variety of age groups and nationalities ((* mark Norwegians tests) Andersson, 2000; Andersson, et al., 2000; Batterham, Stanisstreet, & Boyes, 1996; Boyes, Chuckran, & Stanisstreet, 1993; Boyes, Stanisstreet, & Papantoniou, 1999; Christidou, & Kouladis, 1996; Cordero, 1999, 2001; Daniel, Stanisstreet, & Boyes, 2004; Fisher 1996 (chap. 5), 1998a, b, c; Francis, Boyes, Qualters, & Stanisstreet, 1993; Gautier, Deutsch, & Rebich, 2006; Hansen, 1993*; Henriksen, 1998*; Henriksen, & Jorde*, 2001; Jeffries, Stanisstreet, & Boyes, 2001; Kerans, & Carlson, 2003; Kerr, & Walz, 2007; Koulaidis, et al., 1999; Lee, Lester, Ma, & Jean-Baptiste, 2007; van Marion, 1989*; Mason, & Santi, 1998; Meadows, & Wiesenmayer, 1999; Mikkelsen, 1996*; Moran, & Morgan, 1993; Morgan, & Moran, 1995; Potts, Stanisstreet, & Boyes, 1996; Rye, Rubba, & Wiesenmayer, 1997; Schreiner, Henriksen, & Hansen, 2005; Turmo, 2003).

The same confusions are also found among teachers and student teachers (Boyes, Chambers, & Stanisstreet, 1995; Dove, 1996; Ekborg, & Areskoug, 2006; Gayford, 2002; Groves, & Pugh, 1999; Hansen, 2003*; Hillman, Stanisstreet, & Boyes, 1996; Khalid, 2001, 2003; Matkins, Bell, Irving, & McNall, 2002; Papadimitriou, 2004). Teacher training and in-service education therefore seem crucial to improve pupils and students' understanding of the climate topic and has indeed been reported to have considerable positive influence both on personal knowledge and teaching skills (Gayford, 2002; Hansen, 2003*; Hillman, et al. 1996).

Mikkelsen (1996) tested Norwegian pupils (n = 562) at age 16 years from Oslo (capital) and surrounding communities in 1994 on environmental issues. 50% meant they had learned most about the concept ‘greenhouse effect’ at school and 26% most from media. About the ‘ozone problem’ the results were respectively 50% and 36%. Jeffries, et al. (2001) found that 85% of undergraduate students had learned ‘a lot’/’something’ about greenhouse effect from school, 56% from television, 53% from newspaper and magazines. The media researcher Wilson (1999) found that 50.7% of college students said that media were their primary source of climate change knowledge. However, “The global warming story is one of the most complicated stories of our time. … Reporters also exhibited confusion about the science of climate change”. For instance 32% of the reporters believed that the theory was still strongly debated, and explained why:

> Much climate change reports focused on a small area of scientific debate. Controversy is great for ratings and circulation, but obviously constrains effective climate change reporting and public education. (Wilson, 1999)

Not only information, but also misconceptions about these environmental issues may be caused and maintained by the mass media (Bingle, & Gaskell, 1994; Boyes, et al., 1995; Boyes, et al., 1992, Henriksen, et al., 2001*; Kahlid, 2001, 2003; Lijnse, Eijkelhof, Klaassen, & Scholte, 1990; Wilson, 1999).

> Children and students may gain ideas, perhaps erroneous from these [popular] media. … Even if media is fully accurate, observers carrying erroneous conceptual frameworks may misinterpret information and generate internal misconceptions which go unchecked. (Boyes, et al., 1995)

Since mass media reports are exchanged between several countries, and are read and seen by people at all ages, Henriksen, et al. (2001) suggest that media might cause the universal finding of confusion between the global warming and the ozone depletion reported.

In the light of the described five lines of evolution, descriptions of the changing curricula, research on pupils and teachers understanding, and media's contributions, the research question is:

> *Has there been any development regarding the knowledge of the greenhouse effect and the effects of the ozone layer among pupils finishing compulsory education during 1989-2005 – in the light of a change of curriculum content and trends of increased media focus and public awareness?*

Methodology

On the test in 1989 the greenhouse effect and the ozone layer were not topics in the curriculum, but had moved into media and public attention during the last years. There were no known tests on pupils' conceptions of the greenhouse effect and the effects of the ozone layer to copy or get inspiration from. 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" (Hansen, 1989, p. 22, my translation). 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 people thought that a hole in the ozone layer could cause global warming. Which of the atmospheric gasses were causing what effects were also very diffuse at that time. These common misunderstandings were used to construct the distractor statements. The exchange or confusion of the greenhouse effect for the effects of the ozone layer is still problems in the media, and the public and political debate (Schreiner, et al., 2005). That's why the questionnaire from 1989 could be used in 1993 and even in 2005.

[Insert table 1 about here]

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 the media parallel or synonymous with CFC. In 1989 many thought (some still think) that CFCs are used as propellants in spray cans – despite the fact that 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 in 1989 (n=348, 168 girls, 177 boys, 3 unknown) was from 7 schools in urban Oslo (the capital) and suburbs (Hansen 1989; 1996, pp. 102-103) all having M74 as curriculum. In 1993 the sample (n=354, 174 girls, 176 boys, 4 unknown) was from 5 of the schools in 1989, plus from 10 schools in rural districts (inland East–Norway 5, costal Vest-Norway 5) (Hansen, 1996, p. 231), all having M87 as curriculum (pp. 510-519). The same schools participated in 2005 (n=440, 206 girls, 233 boys, 1 unknown) all having L97 as curriculum. Using the same schools makes χ^2-testing for significant changes 1993-2005 relevant. Because of the differences in sampling, the changes 1989-1993 are not tested, only mentioned as 'trends' if they are clear. The samplings were done administratively not randomized i.e. used classes at hand from schools chosen to cover different districts of Oslo and geographically different rural communities. The samplings limit the external validity i.e. the possibility to generalize the results to the population. However, the samples are relatively large and from both urban and rural communities all over southern Norway in 1993 and 2005.

Results and discussions

Responses to the <u>right</u> greenhouse effect statements

Everyone, including pupils exchanging or confusing the greenhouse effect for the effects of the ozone layer, should respond correctly to the last statement in table 1: *The greenhouse effect is necessary for life on the Earth* – as are both the greenhouse effect *and* the ozone layer. In 1989 only 23.3% of the pupils agreed with this 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 future global warming. In 1989 the pupils did not get any corrective from formal learning. The natural science textbooks were written to curriculum M74, and the teachers were not educated to teach and answer questions about such new environmental and scientific problems. Both pupils and teachers had media as their primary information source.

No similar statements are used in other studies to the same age group, but Andersson, et al. (2000) reported that about 10% of Swedish pupils 15-16 years old (n=201) "clearly refer to the natural greenhouse effect as such" when describing what the greenhouse effect is. About 40% only express the enhancement, and the rest of the answers concern the "ozone effect". Among first- and second year English student teachers only 37% agreed, before instruction, that "If there was no greenhouse effect, none of us would be here", 46% disagreed and 17% did not know (Dove, 19966). 63% of American pre-service teachers agreed that "The greenhouse effect is primarily the result of human activity" (Kahlid, 2001). 89% of American pre-service high school teachers agreed that "The greenhouse effect is completely the result of human activity" (Kahlid, 2003). It seems to be confusion between the natural and increased greenhouse effect even in our days both among pupils and teacher students.

In 1993 the number of right responses was still very low (30.5%) despite the fact that the curriculum M87 (1987, p. 246; 1990 p. 267) prescribed teaching about 'changes in the weather and climate'. The concept 'greenhouse effect' was not named in the curriculum, but was used in some textbooks. Some textbooks also had texts about the ozone problems, which was not a topic in the curriculum (Hansen, 1996, pp. 286-321). 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 a routine, distinguishing the normal greenhouse effect from the increasing greenhouse effect.

The test in 2005 shows a significant improvement ($\alpha<0.5\%$) from 1993. 75.0% of the pupils agreed with the statement: *The greenhouse effect is necessary for life on the Earth.* The cause might be improved teaching and formal learning. The curriculum L97 was in general more binding and precise than M87. L97 (1996, p. 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 than in 1993. From 1992 to 2003 environmental issues were obligatory subjects in teacher education with the greenhouse effect and the effects of the ozone layer as topics (KUF 1994, pp. 227-245).

Pupils' improvement on this statement could also partly be due to better informal learning. Between the tests in 1993 and 2005 there have been a lot of major climate political events all highly focused in the media: IPCC's reports 1995, 2001; Rio 1992, Kyoto 1997, and the Conferences of the Parties every year afterward. Still some research communities are skeptical to the conclusion of IPCC 2001 (p. 10): "There is new and stronger evidence that most of the warming observed over the last 50 years is attributed to human activities". Medias' reports about the scientific discussions might have trigged the pupils' interest and the teachers teaching about the greenhouse effect. The information in Norwegian media is year by year becoming more correct and precise. The public worry about global warming, knowledge about the causes, possible consequences, adaptation and adequate mitigation, are increasing.

Such themes are often on the Norwegian political agenda. Therefore the everyday discourse could have been improved and contributed positively to informal learning.

The other two right statements are about causes and effects (table 2). The trends on both are very good from 1989 to 1993. Despite all good reasons for further improvement 1993-2005 given in this paragraph, the knowledge about *Increased burning of coal, gas and oil increases the greenhouse effect is* on the same level in 1993 and 2005. Perhaps the statement was well known and considered possible already in 1993 i.e. 'two of three' are near an upper limit? Or more likely, this statement is not so personalized to Norwegian youths, because we use only hydropower, not coal, gas or oil in the production of electric energy used in our homes.

After the very good trend from 1989 to 1993, it is rather disappointing and difficult to explain that the knowledge about *The greenhouse effect is caused by carbon dioxide gas (CO_2)* has decreased significantly from two of three respondents in 1993 to a good half in 2005 (table 2).

On similar statements to English pupils age 15/16 (n=81) 80% answered 'sure'/'think right' to "The greenhouse effect is made worse by to much carbon dioxide in the air", and 77% to "The greenhouse effect can be made smaller by not using cars so much" (Boyes, et al., 1993). An overview of the results of a series of studies (Schreiner, et al., 2005) shows that CO_2 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 even today.

Improved formal and informal learning could have caused the good trend from 1989 to 1993, and the significant increase from 1993 to 2005 in a number of double-responses to the two right cause/effect statements about the greenhouse effect (table 2). However, in 2005 neither 44.5% seems impressively high, nor do the numbers of responses to the two single cause/effect statements, 57.7% and 66.1% respectively.

[Insert table 2 about here]

Responses to the <u>wrong</u> greenhouse effect statements

Four of the statements are distractors i.e. wrong 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 Stanisstreet, & Boyes's (1996, pp. 37-52) theory of over-generalization:

> … an overview of the results of a 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. (p. 37)
>
> How children's thinking about the consequences and causes of global environmental problems might be confused by the term 'pollution'. (p. 48)

"Synonyms offered for "pollute" are "contaminate", "infect" and "poison"" (p. 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 90s 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 may also destroy the greenhouse effect. Even today only experts know that CFCs are very potent greenhouse gasses increasing the greenhouse effect, not destroying it.

An 'inverse' theory of over-generalization might explain why an increasing number of pupils (table 3) 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 protects us against one environmental global threat should then protect us against other threats according to an 'inverse' theory of over-generalization.

The distractor *The greenhouse effect makes the temperature fall* has a rather low rate of agreement in all tests (table 3). 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. Secondly, in 1989 media and lay persons did not, and some still do not, discriminate between the normal greenhouse effect and the increasing greenhouse effect causing global warming. Global warming means rising temperature, not falling. Thirdly, those who discriminate might know that the (normal) greenhouse effect causes steady global average temperature levels over years due to the balance of incoming and outgoing radiation.

Ozone in the ozone layer protects us against UV radiation from the sun. This scientific fact was part of the media information coming along with the discovery of the Antarctic ozone hole in 1985. In the years to come the ozone hole in the Antarctic, the discovery of a general global depletion and the processes leading to the Montreal protocol in 1987, were well reported in the media and were on the political agenda. In the light of such information the statement *The greenhouse effect is caused by ozone gas (O_3) in the ozone layer* was in 1989 and 1993 seen as a clear distractor supported by only 14.9% and 17.5% respectively (table 3). 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 responsible for only 6.5% of the total greenhouse effect. In 1989 only experts were aware of that fact. However, ozone is far 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.

Pupils' responses on similar wrong statements about the greenhouse effect are on equal or higher level in several of the reported articles (above). There seems to be an overwhelming general confusion of climate change with the ozone issue.

[Insert table 3 about here]

Responses, an overall look

The results in table 4 confirm results from a series of international studies reported above (for an overview see Schreiner, et al., 2005) showing that many pupils exchange the greenhouse effect for the effects of the ozone layer or confuse facts about the two effects.

That is also the fact in two other Norwegian tests in 1990 and 1994 both on 16 years olds pupils from urban areas in Trondheim and Oslo respectively. In van Marion's (1990) test (n=258) 35.7% responded wrong to the statement (my translation) "Do you connect destruction of the ozone layer to carbon dioxide (CO_2)?" 47.3% thought it was sulfur dioxide

(SO_2). Only 27.1% responded that none of these gasses destroyed the ozone layer. 74.8% responded right to "Do you connect carbon dioxide (CO_2) to the greenhouse effect?" 20.9% thought it was SO_2 and 11.2% none of them.

On Mikkelsen's (1996) test (n=562) in 1994 59% responded right on the statement (my translation) "CFC gasses contribute to destruction of the ozone layer". 11% responded wrong and 30.2% did not know. The results on statement "CO_2 contributes to the greenhouse effect on earth" were respectively 61%, 18%, 20.5%. On statement "CO_2 contributes to destruction of the ozone layer" only 35% responded right i.e. 'no', 56% wrong and 9.0% did not know. To the question: "What would happen if the greenhouse effect increases?" 50% answered that the ozone layer would be thinner.

Like the present tests, the exchange and confusion between the two effects is obvious both in van Marion's and Mikkelse's material. Because of different statements and presentation designs the level of exchange and confusion is difficult to compare with the figures in table 4 for 1989 and 1993.

After a very good trend from 1989 to 1993, the tests in 1993 and 2005 show that the number of pupils exchanging the two effects has stabilized just below 20%. The number of pupils confusing facts about the two effects (responded both to right and wrong statements) show a very negative trend from 1989 to 1993 and is significantly further increased from 1993 to a very high level (51.1%) in 2005. The sum of pupils exchanging or confusing the effects is 70.4%, i.e. only ca.30%, has not agreed with any wrong statements at all in 2005. This is a significant decrease from ca.50% in 1993, accelerating the negative trend from 1989 to 1993. Some of the same tendencies are found among undergraduate students in 2001 compared to 1992 (Jefries, et al., 2001).

The boys performed better than the girls (significant on level $\alpha<2.5\%$, not on $\alpha<0.5\%$) at the test in 1989 (Hansen, 1989, p. 31). The standard deviation is big in both groups. There are big but not significant differences between the schools (p. 33). Since these topics were not included in the curriculum and therefore not part formal teaching, the big variances might indicate that the pupils' benefit from informal learning is very different.

The boys still performed better than the girls (significant on level $\alpha<2.5\%$, not on $\alpha<0.5\%$) at the test in 1993 (Hansen, 1996, p. 512). The variances are still big in both groups. There was no significant difference between the three districts (urban Oslo, rural inland, rural costal) (p. 512). The variances are big in all districts, especially in Oslo. The interviews (n=37, pp. 550-562) show that most of the pupils (91.9%) are aware that the local climate might change in the future. The cause is either increased greenhouse effect (15.2%), depletion of/hole in the ozone layer (42.4%) or both (18.2%). The results from interviews confirm the results from the questionnaire.

On the last test in 2005 there was no significant difference between boys and girls, unlike reported by Jefries, et al. (2001) who found that female undergraduate students held more misconceptions than males, but was more wary of the hazards coming with a warmer climate. There was no significant difference between the three districts. The variances are still big in both genders and in all districts.

[Insert table 4 about here]

Table 3 and 4 show disappointing results in 2005: A significantly increased number of pupils support a single wrong greenhouse effect statement, and many confuse the two effects. Three of the wrong 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 disappointing results could be that factual knowledge about the ozone layer, like the three 'changed' statements, has 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 not that often on the agenda in the media as in the period 1985-1995. This might be an effect of the good impact on the ozone layer from facing out production and the 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 public and political concern about the ozone layer are fading out from media and people's minds, the focus on the increasing greenhouse effect, global warming and the causes and consequences have been high on the agenda both in the media, in politics and among lay persons in Norway for all the last ten years. This double development influences the pupils' informal learning about the ozone layer. So has perhaps also the arena for formal learning about the ozone layer, since less media focus might lead to less interest among pupils and teachers. Low interest is a poor condition for learning about the ozone layer. At the same time the interest in and questioning of the greenhouse effect problems have increased, and the teachers might have concentrated their teaching of atmospheric problems in that direction. Because the pupils do not have enough adequate factual knowledge about the ozone layer, the effect is that the pupils had difficulties in seeing that the distractors (table 3) easily could be changed into right ozone layer statements.

Conclusions

This article is the first international presentation of the first known test on pupils' knowledge about the greenhouse effect and the effects of the ozone layer. For analyzing the development of this knowledge, the questionnaire from 1989 is used at the some of the same schools in 1993 and 2005. Discoveries and research results on changes in the greenhouse effect and the effects of the ozone layer during the 1980-ies increased the media focus and triggered off 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 topics were stepwise introduced in the Natural science curriculum for compulsory school from nothing in 1974 to explicit learning aims on both topics in 1997. In 1989 only one out of four 15-years old pupils did know that the greenhouse effect is necessary for life on the Earth. In 2005 three out of four knew. Both formal learning in school and informal learning from media and public discourse might have contributed to increased knowledge.

From the late 1990-ies the media and public interest in ozone problems have decreased thanks to retardation in the development of ozone layer depletion. At the same time there has been an increased focus on increasing greenhouse effect and global warming. This double situation might have influenced the teaching and learning in the compulsory school in a way that might be the answer to why factual knowledge about the causes and effects of the greenhouse effect has decreased and the confusion of the greenhouse effect for the effects of the ozone layer has increased from 1989 to 2005. The confusion could perhaps partly be a result of pupils' tendency to over-generalize environmental problems caused by the use of the concept 'pollution' in different contexts.

News and recommendations

A new national curriculum was implemented in the autumn 2006 as part of the reform named *Knowledge promotion* (*LK06*, 2006a) covering both the 10-year compulsory school and upper secondary education and training. The curricular topics for this article have unfortunately

been moved from compulsory school grade 10 to upper secondary grade 1 in the programmes for Specialization in general studies, Sports and physical education and Music, dance and drama. These programmes include only 43.3% of all students in 2007 (Utdanningsdirektoratet, 2007). For students on the vocational education programmes (56.7%) the topics are not compulsory, i.e. more than half the population of Norwegian youth do not get formal education in these topics any longer. Is it 'knowledge promotion' when half the population do not get formal education about global warming, agreed as the global environmental problem Number One and in the United Nations Decade of Education for Sustainable Development?

For the lucky 43.3% of the youth population, the competence aims are (LK06, 2006b, p. 9):

> The pupil shall be able to
>
> - explain the importance of the ozone layer with respect to solar irradiation of the earth
> - explain what the greenhouse effect is and elaborate on and analyse how human activities are altering the energy balance of the atmosphere
> - elaborate on some possible consequences of the increased greenhouse effect, including in Arctic areas, and the measures that are being initiated internationally to reduce the increase in the greenhouse effect

This is a clear extension of the topics from L97. Without any argumentation, LK06's aims are a reflection of United Nations Decade of Education for Sustainable Development (2005-2014) and of the severe analysis from the IPCC report in 2001 – confirmed and reinforced in 2007. All three assessment areas of the IPCC reports are now included, setting the problem of global warming in a social and natural context. Despite the positive development of the ozone problems, they are still in the curriculum. Partly because ozone depletion and polar ozone holes are still severe problems and will be so for decades, and partly because of the problems of the confusion and exchange of the effects of the ozone layer for the greenhouse effect addressed in this and numerous other articles.

Several of the reported articles about pupils and students conceptions of the greenhouse effect and the effects of the ozone layer give recommendations for teaching those topics. Assuming that the trends and analysis in this article are true, one recommendation for promoting 'education for sustainable development' with regards to increased greenhouse effect and prolonged ozone-problems might be Boyes, et al.'s (1995) 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.

It might be useful to link the conceptual problems to hands-on experience when possible. For example the basic physical processes like transmission, reflection, absorption and emission of different wavelengths of electromagnetic radiation could easily be illustrated through student experiments or teacher demonstrations (Hansen, 2003).

Media and The Internet are often setting the agenda for the public debate on environmental problems. A second recommendation is to use these sources actively in the teaching of the scientific as well as the societal, political, ethical and other aspects of the problems. Role play is powerful, for instance a 'Climate Conference' or 'Panel-debate on TV'

where pupils work out their own facts-sheet for one character based on information from media (Hansen, 2003). Media and The Internet (and text books) could be sources when making a quiz. Each student works out many questions and answers. Groups of 3 or 4 students fight against each other in a cup system ending up with a final (ibid.).

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 and political and practical action. This could be done in 'Discussion Groups' or pairs (like reported in Andersson, 2000, on "How should the emission of carbon dioxide per person and year be limited in developing countries and industrialized countries?"). An alternative is a 'Consensus Conference' where social aspects of science are included in evaluation and validation of knowledge claims (reported on another topic by Kolstø, 2000).

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

Put a cross at the information about the greenhouse effect that is right in 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 the Earth.*

Table 2. Responses to <u>right</u> cause/effect greenhouse 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
<u>No</u> answer	5.5	5.0	0.0

Table 3. Responses to <u>wrong</u> 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*

Table 4. **Responses, an overall look of the statements** (*% response*) - excepted the statement *The greenhouse effect is necessary for life on the Earth.* *Significant increase (α<0.5%) 1993-2005.			
	1989 n=348	1993 n=354	2005 n=440
Exchange greenhouse effect with effects of the ozone layer. No right, some wrong responses.	26.4	17.5	19.3
Confuse greenhouse effect with effects of the ozone layer. One/two right, some wrong responses.	18.1	32.8	*51.1
Sum of Exchange and Confusion	44.5	50.3	*70.4