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Teachers' understanding of climate change

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Abstract

The climate change topic has been included at the framework curricular documents in the Czech Republic since 2007 but who should teach about climate change at the schools remains unclear. In 2011 we conducted a research on teachers' understanding of climate change with questions focused on how the climate system works. The upper-primary teachers performed significantly better than the lower-primary teachers and physics teachers showed significantly better knowledge compared to the rest of the teachers. Educational resources on climate change are missing in the Czech Republic. We developed an on-line educational application on modeling global CO₂ emissions.

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1. Introduction

Providing an adequate climate literacy to the next generation remains a challenge. Climate science has made a great progress in the last decade and also the climate system itself has shifted towards a hotter state. The interdisciplinary climate science belongs to the Earth science. The subject of the climate change research consists of all Earth spheres including the anthroposphere. Basic principles of the climatic system are described by natural sciences - mainly physics, chemistry, biology and geology. Transformation of the climate science system into the didactic system is a great challenge because of its complexity. Formal education in the climate change topic requires a systematic approach, collaboration of teachers and a good coordination during the educational process. Currently, many countries aim to implement the climate change topic into their national curricula and to improve the efficiency of education towards a climate literate society.

Some universities, governmental or non-governmental organizations have been monitoring attitudes of the public towards climate change. Several international studies have investigated the state of pupils' and students' understanding of global climate change related issues. Studies of this kind rarely focus on teachers, who ought to deliver the knowledge to the next generations within the frame of formal education. The National Center for Science Education (NCSE) reports that American teachers often face pressure to teach "both sides" of the issue - meaning they are forced to teach also the non-scientific arguments denying anthropogenic causes of the global climate change. The situation resembles the efforts of American creationists to discredit the scientific theory of evolution by implementing creationism into school curriculum. Teaching religion at USA public schools is forbidden by the constitution. Because of religious background of creationism the constitution protects pupils from being manipulated by religious groups including creationists. In case of the climate change topic the defense is more difficult because no law prohibits teaching a bad science. Public opinion worldwide is influenced by climate change deniers who have been more effective communicators using all available media channels, than the scientists publishing in peer-reviewed journals. The gap between the knowledge of climate scientists and the public has been widening.

In 1992 almost all nations agreed on the UNFCCC (United Nations Framework Convention on Climate Change) declaring the commitment to develop and implement an education about climate change and its effects on national and regional levels and to develop and share educational programs and materials (article 6 on education, training and public awareness). Since 2011 the USA use "A Framework for K-12 Science Education" which requires the students' knowledge of global climate change as a part of science education (section ESS3.D). The European Commission recommends to implement the climate change topic to the formal national education through the Education for the sustainable development. Education about climate change differs in European states. Uherek (2008) published a paper summarizing opinions of European teachers on the state of the education about climate change in their countries. Generally, teachers assess the information presented to pupils as scattered and not comprehensive.

The climate change topic has been included at the framework curricular documents in the Czech Republic since 2007. But there are no official rules or recommendations on who should be in charge of teaching climate change at schools. In the Czech Republic the natural science is usually taught as an integrated subject at lower-primary schools (grades 1-5) and divided to physics, chemistry, biology and geography at upper-primary schools (grades 6-9) and secondary schools (grades 10-13). The compulsory education consists of 9 grades: lower-primary school (grades 1 to 5) and upper-primary school (grades 6 to 9). Skilled pupils have a choice to attend "gymnasium" which provides more general and academic knowledge in order to prepare the pupils for university studies. Gymnasiums have 4, 6 or 8 grades finalized by the maturita exam at the end of 13th grade. 8-year gymnasium is divided into two levels: lower (same level as upper primary school) and higher (same level as secondary school). Czech schools can decide themselves whether to teach science as an integrated subject. Usually, lower-primary schools teach integrated science but upper-primary schools, both levels of gymnasiums and secondary schools teach differentiated subjects – physics (grade 6 and above), biology (grade 6 and above) and chemistry (grade 8 and above). The basics of the climate change belong to the system of natural sciences, thus schools can teach the topic at scientifically oriented subjects. Many aspects of the Earth climate system have been included in the curriculum and textbooks of different school subjects. From such scattered information it is very difficult for the pupils to connect the dots and to understand how the climate system really works.

In 2011 the Czech organization AMO (Association for International Issues) surveyed the knowledge and opinions of gymnasium teachers concluding with the following findings: The climate change topic is taught at

several subjects. The topic requires interdisciplinary approach and comprehensive materials. Teachers find the topic important, complicated and the lesson preparations time consuming. Over three quarter of the respondents assesses the currently available textbooks as insufficient and 87 % of the respondents seek for supplementary materials. The dominant majority of the respondents teach about the climatic cycles, influences of humanity on the climate and scenarios of the impacts of climate change. Students actively participate on the lessons.

Teaching climate change topics requires climate literate teachers in the first place. Many organizations including NASA, NOAA, NSF have been providing grants to increase public awareness about global climate change and to improve the state of education by preparing extended curricula, educational materials and by educating primary and secondary school teachers. For example, since 2003 EGU (European Geoscience Union) has been providing one-week seminar GIFT (Geophysical Information for Teachers) to the groups of approx 70 European teachers within the EGU General Assembly in Vienna. Each year there is a different topic of the seminar. Passed topics were: Water; Ocean Acidification; Evolution and Biodiversity; Energy and Sustainable Development; Climate Change, Natural Hazards, and Societies; The Earth from Space; The Carbon Cycle; Geosciences in the City; The Polar Regions; The History of the Earth; Oceans. All the topics more or less relate to climate change. Teachers attending the seminars learn climate science directly from the scientists and share their teaching experiences.

In order to investigate the state of understanding of the climate change topic by Czech teachers we conducted the following survey.

2. Methodology

In 2011 we made research on teachers' understanding of climate change collecting data using an on-line survey form. The survey questions were focused on how the climate system works, which is a domain of climate physics. They were selected and translated to Czech from the Yale Project on Climate Change Communication "Americans' Knowledge of Climate Change". Using the survey we tested whether the following three hypotheses hold. Just the first two did:

- H1 Teachers of physics have a better understanding of the climate system compared to the rest of the teachers. *(appeared as true)*
- H2 Teachers of gymnasium have a better understanding of the climate system compared to the teachers of upper primary schools. *(true)*
- H3 Teachers who worry about the climate change have a better understanding. (appeared as false)

Data collection ran March 2.-16. 2011 through an electronic form on GoogleDocs. Our beg for filling the survey was sent to 3 groups of potential responders: 1) 11 Czech schools taking part in the GLOBE program, 2) some 30 teachers active in The Heuréka Project (Czech independent physics teachers association), 3) all graduates of physics, geography, biology and chemistry teaching at the Faculty of Education of Masaryk university in Brno, who graduated 2006-2011.

179 teachers began to fill the form (134 women, 45 males), two of them answered no relevant questions. Further 8 answered just about a half of the questions and could not be included into the sample for hypotheses evaluation. That sample had 171 respondents at last. Most of them are teaching at primary schools.

Filling the survey took 30 min at most. Responders were voluntary and anonymous, obtaining no reward. The questions tested mostly knowledge; proper answers were unequivocal, firmly based in published research. Hypotheses were tested using just 38 suitable answers which could be classified yes or no (the whole survey had 55 questions and many more possible answers). Each correct answer got 1 point. A scale of possible answers was dichotomized to 1 (true) and 0 (wrong) for this purpose. Answers "don't know" and no answer were treated as 0. "Surely yes" and "yes" were treated as YES, "sure no" and "no" as NO. "Much", "significantly" and "a bit" were taken as YES, "not at all" as NO. Non-paired t-test was used for evaluation; Mann-Whitney U test gave a check, giving the same qualitative outcomes, even if the level of significance P was mildly different in some cases. As a significant difference, α =0,05 level was taken.

3. Findings

For H1, the average score of 26 qualified physics teachers was by 2 points better than for the remaining ones with 145 people (27.1 against 24.9, out of possible 38). This difference has been significant at 0.01 level.

For H2, the score increments from lower primary to upper primary to gymnasium teachers amounted to 2 points (22.9, 25.3, 27.1), all significant (P= 0.0034 and P = 0.022). The number of teachers in subsets were 29, 100, 30 – the sum is lower than 171, as some teachers taught at several levels of schools.

For H3, the scores did not differ perceptibly (25.4, 25.2), subsets had 27 and 144 people.

In all these subsets, standard deviations of scores amounted between 3.5 and 4.0.

4. Discussion

In spite of significantly better score of physics teachers, it is quite apparent that the distributions overlap a lot, differing by just half of the standard deviation. Evidently, even relevant background education combined with a lot of practice in school (three quarters of physics teachers taught more than 5 years, an average was 14 years) is no guarantee of good knowledge of climate change causes. But at least, physics teachers are not probable to have extremely poor knowledge of this issue.

The fact that the subset of gymnasium teachers got the same average score might be explained in two ways. Gymnasium teachers may be generally better educated in science than primary school teachers. And issues highly relevant for the whole society are perhaps more discussed in gymnasia, so teachers pay more attention to them and educate themselves even outside any formal system. Worries about the future themselves are evidently no strong motivation to study the broad scope of climate change science.

5. Preparing future teachers

Teachers supposed to transform the scientific information about climate change and to transfer it to the pupils in an understandable manner. Teaching climate change topics at schools could be even counterproductive if the educators were not climate literate. Training primary and secondary school teachers in climate change education methods is crucial. We believe that faculties of education should develop systematic courses of basic climate science education for all their students. Advanced courses should be provided to students of physics, chemistry, biology, geography and students of integrated science who have the most appropriate approbation.

For the last decade our team at the Department of Physics (Faculty of Education, Masaryk University) has been striving to enhance environmental and climate literacy of the students through various projects and educational programs. We have been developing environmentally focused laboratory measurements, educational activities and tools. Currently our team collaborates with the Palacký University on the project "Modules – innovation of physics and chemistry teaching and learning". In the frame of this project we prepare educational activities for the module "Climate and biogeochemical cycles".

In the next chapter we present an on-line application designed as an educational tool for climate change education of students at the Faculty of Education.

6. Sample educational activity: The Kaya identity

Many schools worldwide let the pupils to calculate their personal carbon footprint for the purpose of environmental education. Various simple or more advanced on-line calculators are available on websites of NGO's and other organizations dealing with the Environment. Some schools also investigate the school carbon footprint and engage the pupils to find ways to reduce the school CO_2 emissions (by waste separation, smart tap water management, efficient transportation, installing efficient light bulbs, adoption of renewable energy sources and/or insulating the school building). That is a good way to find out how individuals can contribute to climate change mitigation. Possibilities of reducing CO_2 emissions on national and international scale can be also discussed on the

school level. People have different opinions on climate policy. How to find out which strategy has a potential to succeed?

The speed of global warming and climate change during 21^{st} century depends on future anthropogenic CO_2 emissions from burning fossil fuels and deforestation. The mix of energy sources, more or less efficient technologies, economy performance and number of consumers significantly affect global emissions of greenhouse gases. Politicians, NGO's, industry representatives and other players defending different interests have been lobbying for their way of the climate policy. An exact calculation of the amount of emissions depending on the society development is a very difficult task. But there is also a very simple way of modeling future emissions based on the formula named after its founder – the Kaya identity. The formula allows to calculate future emissions (M) roughly as a multiplication of four parameters: carbon intensity (C/E), energy intensity (E/GDP), economy output per capita (GDP/N) and population (N). The Kaya identity gives quite a good estimate of CO_2 emissions and is also used in the studies by the International Panel on Climate Change (IPCC) or International Energy Agency (IEA).

The University of Chicago released a simple Kaya calculator of global emissions on its website (see forecast.uchicago.edu/Projects/kaya.html). More sophisticated calculator, just for the emissions of the United Kingdom, was prepared by David MacKay, chief scientific adviser to the UK Department of Energy and Climate Change (see go.nature.com/1wfvnx). Its simplified version is very useful for educational purposes (see my2050.decc.gov.uk). These interactive tools allow everyone to model future emissions based on users assumption of demographic, economic and energy sources changes.

We developed another on-line global CO_2 emissions calculator based on the Kaya identity having some new features (see ped.muni.cz/kaya). The Kaya identity itself does not include emissions from deforestation and land use changes. Our new calculator enables to add these emissions to the fossil fuel emissions calculated by the Kaya identity. The user can set up the parameters for each of the next 4 decades. The output of the calculator is the probability of exceeding the critical global temperature rise of 2 K above the preindustrial level for the inserted combination of parameters. The values of the cumulative CO_2 emissions and boundaries of 25 % and 50 % probability were taken from the study published in the journal Nature (Meinshausen 2009). The user can calculate future global emissions based on the assumption of the particular society development. Some people expect "business as usual" scenario and others "green growth", "peak oil" or economic collapse etc. We intend to use the calculator for the extension of environmental education of our students from natural science labs to the social sphere. The calculator is available on-line and free to use for anyone interested.

7. Conclusion

Although the Czech Republic declares a compulsory education on climate change issues, in reality teaching of the topic has been problematic. Through our research we discovered that physics teachers have relatively good understanding of the climate system, and thus have good preconditions to teach climate science. We also found out that gymnasium teachers have better understanding of climate system than upper-primary teachers. Worries about global warming did not correlate with the knowledge of the respondents.

As a free educational tool we developed an on-line application on modeling future global CO₂ emissions from burning fossil fuels and deforestation (available on-line: ped.muni.cz/kaya). The application can be used during the school lessons on climate change mitigation.

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