

“Tutorials in Climate Change”: Teaching scientific concepts underlying climate change

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Abstract. Amid global uncertainties, climate change education is essential to empower students. In this workshop, we introduce *Tutorials in Climate Change*, designed to enhance conceptual understanding in the context of climate change through practical problem-solving and addressing prevalent misconceptions. Additionally, the tutorials incorporate concept cartoons and an anchored instruction approach and focus on students' reasoning. The target group are upper secondary students and future teachers. Results from an evaluation with future teachers indicate a substantial positive development in their conceptual understanding. In the workshop, tutorials and background information will be provided and implementation scenarios will be addressed.

Introduction

Students face growing uncertainties due to global climate change, impacting various aspects of their lives [1]. To empower them in this challenging scenario, providing basic climate change education in school is crucial, including the development of informed attitudes, skills, and an understanding of the fundamental principles of Earth's climate system [2]. Five concept areas have been described as essential to understanding climate change [3]: (1) Earth's atmosphere, (2) the difference between weather and climate, (3) climate as a system, (4) the carbon cycle and (5) the greenhouse effect. In the workshop, we will present ten so-called *Tutorials in Climate Change* [4] addressing these five concept areas. These tutorials are intended to be used in teacher education programs and upper secondary school teaching. Accordingly, we will discuss application scenarios in the workshop and provide background information on effective implementation.

The tutorial-approach in climate education

Tutorials that let students practice solving qualitative problems and explaining their reasoning have been described as effective in deepening student understanding [5]. We therefore focus on students' explanations for their reasoning in our *Tutorials in Climate Change*. Furthermore, we base each of our ten tutorials on alternative conceptions that are widespread among high school students [6], aiming to support conceptual change [7] towards a scientific conception. To confront and reflect various conceptions, we use concept cartoons [8]. Students are asked to assess the statements in a concept cartoon explaining their reasoning. In the end of each tutorial, after engaging with new information, students are asked to go back to the concept cartoon and re-assess their original evaluation of the statements as well as their reasoning.

Additionally, our tutorials follow a modified anchored instruction approach, since research has emphasized the importance of situating instruction in contexts that are meaningful [9]. Each tutorial starts with an authentic anchor like a newspaper clipping or a weather forecast. This provides an opportunity to work from a shared experience perspective. In the concept cartoon, information from the anchor is discussed, setting the stage for all further tasks.

Students then engage with new information in various tasks designed to foster conceptual change towards the scientific conception. The final task of re-assessing their original evaluation provides an opportunity to reflect on the learning process and strengthen the new conception.

To support implementation in the classroom, each tutorial is accompanied by a short teacher guide. This teacher guide provides the learning goal, the scientific key idea(s) addressed in the tutorial, possible alternative conceptions, scientific evidence, as well as background information and follow-up possibilities.

Implementation possibilities and effectiveness

The *Tutorials in Climate Change* were designed to be used in upper secondary school teaching and teacher education programs. Workshop participants will be provided with the tutorials including teacher guides, background information on their development, and a discussion of underlying assumptions and considerations. We will further discuss possible implementation scenarios and provide suggestions in this regard.

At the date of submission deadline, the tutorials have been tested with $N=44$ future physics teachers from Austria, Belgium, and Germany in a pre-post format. First results show that the future teachers positively developed their conceptual understanding of climate change ($t(82) = 5.1$, $p < .001$) with a large effect size ($d = 1.11$), as measured with the CCCI-422 instrument [3].

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